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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

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(Continued on inside back cover)

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Life History of the Hawaiian Monk Seal

KARL W. KENYON and DALE W. RICE[1]

THE HAWAIIAN MONK SEAL, *Monachus schauinslandi* Matschie, 1905, has long remained one of the rarest and least known of marine mammals. Few zoologists have been able to reach the remote mid-Pacific coral atolls on which it breeds, and their visits have been brief. While engaged in zoological studies in the Leeward Chain of the Hawaiian Islands, we were able to observe these seals from aircraft throughout their principal range, and to make detailed studies of those inhabiting Midway Atoll. We also landed on Green Island in Kure Atoll. Our field study covers the period from November 17, 1956, to October 11, 1957.

We gratefully acknowledge the help of the following: J. W. Aldrich, P. L. Breese, V. E. Brock, E. H. Bryan, M. B. Chitwood, C. F. Clagg, E. Y. Dawson, R. Dodge, P. A. DuMont, L. A. Faye, Y. J. Golvan, J. E. Graves, E. Y. Hosaka, P. L. Illg, E. C. Jones, C. R. Joyce, J. E. King, J. A. Neff, G. H. Pournelle, W. Pointon, R. A. Rausch, F. Richardson, C. S. Robbins, V. B. Scheffer, D. W. Strasburg, S. W. Tinker, A. L. Tester, K. Waldron, K. A. Wong, and D. H. Woodside. The help of Naval personnel stationed at Midway was invaluable, particularly that given by Capt. E. T. Hughes, Comdr. J. L. Hooper, Lt. Comdr. D. E. Moritz, Lt. Comdr. J. F. Reilly, Lt. D. H. Picht, Ens. R. T. Takahashi, and Chief J. H. Green.

HISTORY

Sealing expeditions during the middle of the 19th century reduced the Hawaiian monk seal population to near extinction. Undoubtedly guano diggers, bird hunters, and whalers further depleted the remnant during the late 1800's and early 1900's. In 1824 a sealing expedition by the brig "Aiona" was thought to have taken the last monk seal; but after a "sealing and exploring voyage" to the Leeward Islands between April 26 and August 7, 1859, Capt. N. C. Brooks of the bark "Gambia" returned to Honolulu having . . . "on board 240 bbls., seal oil, 1,500 skins. . . ."[2] During six weeks on Laysan in 1911, Dill and Bryan (1912) and their party watched for seals but saw none. They were told by Max Schlemmer that during the 15 years he had lived on Laysan, seven seals had been killed. One of these was the specimen given to Schauinsland in 1896, upon which Matschie (1905) based the description of the species. During subsequent years, the few expeditions visiting the Leeward Chain reported increasing numbers of seals (Bailey, 1952). For a more complete historical treatment, see King (1956).

[1] Biologists, U. S. Department of the Interior, Fish and Wildlife Service, Sand Point Naval Air Station, Seattle 15, Washington. Manuscript received March 3, 1958.

[2] *The Polynesian*, August 13, 1859. We question this report for the following reasons: (1) In view of present populations, if in 1824 the seals were nearly wiped out, it seems doubtful that 1,500 could have been taken on a 103-day voyage in 1859. The reported take of seals indicates an average of about 15 seals per day. During this period, more than 2,200 miles were covered and explorations made in uncharted waters. (2) Seals are characteristically scattered along many miles of beach. These beaches are difficult of access from the sea. Skinning seals, scraping and curing skins, collecting and rendering the blubber of many widely separated individuals would have been a tremendous undertaking. Therefore, we made a careful search for the journals and log books of Capt. Brooks. His daughter, Miss Dorothy Brooks, told us that these were lost in the San Francisco fire of 1906. (3) In spite of the fact that *The Polynesian* gives an otherwise detailed report of the "Gambia's" voyage and explorations, including accounts of various wildlife species, it mentions seals only in the lead paragraph, as quoted above.

Seven monk seals have been captured on French Frigate Shoals, with the assistance of the U. S. Coast Guard, and one at Pearl and Hermes Reef. These were held in captivity in the Honolulu Zoo, the Waikiki Aquarium, and the San Diego Zoo. One seal is still living in the Waikiki Aquarium after more than two and a half years in captivity, and another in the San Diego Zoo. Others have been kept for relatively short periods (Table 1).

TAXONOMY

Monk seals are the only phocids of tropical and subtropical waters. The genus *Monachus* is represented by three relict populations with a widely disjunct distribution. Their probable origins and relationships have been discussed by King (1956). It appears that the Mediterranean monk seal, *M. monachus*, is specifically distinct from the Caribbean monk seal, *M. tropicalis*, and the Hawaiian monk seal, *M. schauinslandi*. The differences between the latter two are slight and have not been verified by comparison of adequate series of specimens of known sex and age. From the few specimens we have examined, certain distinguishing characteristics ascribed to *M. schauinslandi*—especially the shape of the palate and the shape of the zygomatic branch of the squamosal—do not appear to be constant. The form of the anterior border of the nasals and the shape of the infraorbital foramen are the most obvious distinguishing features. The morphological differences between the Caribbean and the Hawaiian monk seals are less than one would expect in two groups of animals so widely separated. Further study may indicate that *M. schauinslandi* should be regarded as a race of *M. tropicalis*.

Monachus is currently recognized as the only genus of the subfamily Monachinae (Simpson, 1945). The close relationship be-

TABLE 1
RECORD OF MONK SEALS HELD IN CAPTIVITY[1]

DATE CAPTURED	DATE DIED	SEX	APPROX. AGE[2]	WEIGHT, LBS.	LENGTH, CM.[3]	WHERE HELD	REMARKS
May 12, 1951	August, 1951	♂	juv	110[4]	143	S. D. Zoo	Cause of death undetermined
May 12, 1951		♂	ad	300[2]	...	Honolulu Zoo	Refused foods; liberated near Kaneohe Bay, November, 1951
April, 1955	July, 1956	♀	juv	90[2]	...	Waikiki Aq.	Died of ulcers
October, 1955	October, 1957	♂	subad	200[6]	...	Waikiki Aq.	Postmortem: large gastric ulcer
August, 1955		♀	subad	230[6]	...	Waikiki Aq.	Alive in November, 1957
September 12, 1956	October 22, 1956	♂	juv	96	131	S. D. Zoo	Cause of death undetermined
September 22, 1956	November 9, 1956	♀	subad	160[2]	168[5]	S. D. Zoo	Acute pneumonia, vegetative endocarditis and peritonitis
July 21, 1957		♂	subad	119[7]	...	S. D. Zoo	Alive in January, 1958

[1] All taken at French Frigate Shoals, Territory of Hawaii, except male taken October, 1955, which was captured at Pearl and Hermes Reef.
[2] Estimated at capture.
[3] Measured at death.
[4] Eviscerated—estimated total weight 125 lbs.
[5] Estimated at death.
[6] Estimated July, 1957.
[7] Weighed at capture. Estimated weight 180 lbs., December 31, 1957.

tween *Monachus* and the Antarctic phocids of the subfamily Lobodontinae has been pointed out by King (1956). Biological similarities, such as voice and certain aspects of behavior, are shared by the monk seal and Weddell seal (*Leptonychotes weddelli*), while the monk seal shares with elephant seals (*Mirounga*) a unique method of molt. It is evident that the Monachinae are even more closely related to the Lobodontinae and Cystophorinae than previously recorded biological data had indicated, and that the three subfamilies are more closely related to each other than any one of them is to the northern "hair seals" (subfamily Phocinae). Trouessart (1897) placed the Antarctic phocids and the monk seals together in the subfamily Monachinae, an arrangement with which V. B. Scheffer agrees (*in lit.*).

DISTRIBUTION

The breeding range of *Monachus schauinslandi* is confined to the islands and atolls of the Leeward Chain, which extends for 1,200 miles northwestward of the main Hawaiian Islands. The Leeward Chain consists of two geologically distinct portions (Bryan, 1942).

In the eastern half are four high volcanic islands: Nihoa Island, Necker Island, La Perouse Pinnacle, and Gardner Pinnacles. These rise precipitously from deep water. The only extensive area of shallow water is French Frigate Shoals, a crescent-shaped atoll containing a dozen sand islets, which half surrounds La Perouse Pinnacle. Paty (1857) gave the following account of a visit to Nihoa on April 27, 1857, ". . . on the sand beach ten or twelve hair seals were found; they didn't take much notice of us until His Majesty [King Kamehameha IV] had shot several, when they became more scared." None were seen at Nihoa between August 7–17, 1940, although looked for (Vanderbilt and de Schauensee, 1941), and Frank Richardson (*in lit.*) who visited the island in late 1953 and again in early 1954 found none. A small breeding colony occupies French Frigate Shoals. They are not reported from Necker or Gardner.

The western half of the Leeward Chain consists of six low coral atolls. From Maro Reef, where only a few rocks are awash at low tide, two monk seals were reported in 1951 (Bailey, 1952). Lt. Comdr. D. E. Moritz flew over Maro Reef twice in October, 1957, and reported seeing no seals. Virtually all Hawaiian monk seals breed on the outermost five atolls: Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, and Kure Atoll.

Wandering seals are occasionally seen among the main Hawaiian Islands. At Hilo Bay, Hawaii, one was killed and eaten by the natives in 1930 (Henshaw, in Dill and Bryan, 1912). Here, perhaps, is an explanation of the restricted breeding range in the Leeward Chain, which had no aboriginal human population. Recent reports from waters of the main islands are shown in Table 2.

ENVIRONMENT

Climate

The fairly uniform subtropical maritime climate at Midway Atoll is typical of the western half of the Leeward Chain. Temperatures near freezing are unknown. Reef corals and their associated fauna grow fairly well but are near the northern limit of their range. They do not occur north of Kure Atoll. Two seasons are well marked. Winter, from early December through March, is characterized by low temperatures, frequent rains, and winds which sometimes reach velocities of 90 miles per hour. These gales cause heavy swells which break violently over the protecting reef and result in rough water in the lagoon. Summer, from April through November, is warm, very humid, and sunny, with occasional showers. The northeast trade winds blow quite steadily but mildly, and the surface of the lagoon and ocean is calm. Mean daily maximum and minimum air temperatures, and mean water temperatures, are presented in Table 3.

During the period March 23 to June 15, 1957, surface water temperatures in Midway

TABLE 2
REPORTS OF MONK SEALS FROM THE MAIN ISLANDS OF HAWAII

DATE	PLACE	OBSERVER	WHERE REPORTED	REMARKS
November 11, 1928	Oahu, windward shore (N.E.)	Thomas M. Blackman	*Honolulu Star-Bulletin*	"... in the vicinity several days."
October 26, 1931	Oahu, north side	J. P. Kaleo	*Honolulu Star-Bulletin*	"Seal frequently seen 3 years ago. ..."
May 12, 1948	Kauai, east side	Philip Palama	*Honolulu Advertiser*	"Seal climbed out of water onto rocks. ..."
October, 1951	Oahu, entrance to Kewalo Basin	Robert Dodge	Letter, December 24, 1957	Seal bit at fishing line about 25 feet from shore
March 30, 1955	Oahu, ½ mile off Waikiki Beach	Gordon Freund	Letter, December 24, 1957	Followed seal below surface while skin diving with aqualung
Early July, 1956	Hawaii, Kaehole Point, Kona Coast	Eddie Y. Hosaka	Letter, August 23, 1957	Seen at 0600, swimming slowly, close to shore
July or August, 1956	Lehua (off Niihau)	Lindsey A. Faye	Letter, August 9, 1957	Large adult hauled out on rocks; photographed

Lagoon were recorded by the Midway Aerology Unit for Kenneth Waldron of Pacific Oceanic Fishery Investigations (POFI). The extremes were 66.7°F. (March 30 to April 5 mean and April 20–26 mean) and 76.8°F. (June 8–15 mean). Since these data differ little from those given in Table 3, they are not included here.

Climatic Adaptation

It is noteworthy that monk seals apparently show few adaptations to a warm climate. We were able to measure the deep body temperature of one 380-pound adult male (BDM 490). This seal had been resting for at least ½ hour prior to death on February 2, 1957, and did not move after it was shot. We immediately inserted a thermometer into a slit in the thoracic cavity. The heart was still beating and the thermometer was bathed in the blood gushing from the severed aorta. The rectal temperature was also taken by inserting the thermometer 5 inches into the rectum. Several readings in both locations were taken alternately. The thoracic temperature was 35.5°C., the rectal 31.1°C. The difference suggests that a rectal temperature taken with a 6-inch thermometer may not be a reliable indicator of body temperature. The deep body (thoracic) temperature of this individual was lower than those reported for other species of pinnipeds. The deep body temperature of a captive harbor seal (*Phoca vitulina*) approximated 38°C. (Scholander, Irving, and Grinnell, 1942). Adult northern fur seals (*Callorhinus ursinus*) at rest had a mean deep body temperature of 37.7°C. (Bartholomew and Wilke, 1956). The average thoracic temperature of nonmolting southern elephant seals (*Mirounga leonina*) was 36.5°C. (Laws, 1956*a*). The rectal temperature of our monk seal was markedly lower than that of sleeping adult northern elephant seals (*Mirounga angustirostris*) which averaged 36°C. during the day and 34°C. at night (Bartholomew, 1954).

The blubber layer on Hawaiian monk seals is light orange in color and about as thick as on arctic and antarctic seals. Our specimen had a heavy layer of blubber over the entire body. Over the mid-belly, it was 42–45 mm. thick. Pregnant females are especially fat but lose weight rapidly during the nursing period. The pup is extremely fat just prior to weaning.

Compared with northern phocids, the pelage of the adults is shorter, the individual

TABLE 3
MEAN AIR AND SURFACE WATER TEMPERATURES (°F.) AT MIDWAY ATOLL

MONTH	AIR[1]			SURFACE WATER[2]
	Mean high	Mean low	Mean	
January	70	62	66	68.4
February	69	62	66	66.8
March	70	63	66	66.4
April	72	64	68	66.9
May	75	68	72	69.5
June	80	72	76	73.6
July	82	74	78	76.4
August	82	75	78	77.5
September	82	75	78	78.1
October	79	73	76	75.8
November	76	69	73	73.2
December	73	66	69	69.7
ANNUAL MEAN	76	69	72	71.8

[1] Data from Aerology Unit, U. S. Naval Station, Midway Island, 1941–57. Highest on record, 92°F.; lowest, 54°F.
[2] Data from Atlas of Climatic Charts of the Oceans, U. S. Weather Bureau, 1938, for the quadrat 175°–180°W., 25°–30°N.

hairs being only about 2–9 mm. long. The pelage of adult phocids can have little effect as a temperature regulator. However, in the young of cold-water seals which have not yet developed a blubber layer, the wooly natal pelage undoubtedly functions as an insulator. At birth, monk seals have a single-layered black pelage consisting of straight silky hairs 6–10 mm. long. In this respect, they differ markedly from the young of arctic phocine seals and antarctic lobodontine seals, which possess a wooly coat about 15–25 mm. long. Pups of the southern elephant seal have a single-layered wooly pelage about 23 mm. long (Laws, 1954). The lack of pelage with marked insulating properties in young monk seals may be a climatic adaptation. In this connection, it is interesting to note that, in young harbor seals, the white wooly fur is retained for several weeks after birth in the northern Bering Sea but is lost in a prenatal molt in southern parts of the species' range (Scheffer and Slipp, 1944).

In addition to black pelage, the newborn monk seal has nearly black skin. It has been suggested that black pigment is a protective shield against harmful insolation. Prior to weaning, the monk seal pup spends much time in intense sunlight on the white coral sand beaches.

Habitat Requirements

Certain features are characteristic of monk seal breeding sites, as follows.

FEEDING AREAS: Seals occur regularly only on islands and atolls having extensive areas of shoal water. At Midway and elsewhere, we frequently saw seals swimming inside the reef but did not see them outside the lagoon, in deep water. That they do range in deep water, however, is evidenced by records far from the breeding grounds and by the fact that remote islands, such as Laysan, have been repopulated after local extermination took place during the 19th and early 20th centuries. Another indication that monk seals may spend considerable time at sea is the observation that certain individuals, when we saw them for the first time, exhibited a heavy growth of green algae in the hair on various parts of the body. The green tinge was lost after a number of days spent on Midway beaches. Food analysis indicates that they feed primarily on bottom fishes, kinds which they could obtain only in comparatively shallow water. In the lagoons, a rich bottom fauna is found on coral reefs and bordering sand areas.

HAULING GROUNDS: Monk seals generally haul out on sandy beaches and sandspits. They are absent from high rocky islets, which lack beaches, in the eastern half of the Leeward Chain. Though they prefer sand to rocks, they are occasionally seen on low, shelving reef rocks which slope into the water on Eastern Island and on reef rocks surrounding atoll lagoons. The southwest side of Laysan Island is bordered by a fairly high ledge of coral rock; we have never seen a seal hauled out along this stretch of shore, although they haul out on the low beaches bordering it. The shade of *Scaevola frutescens*, above the beachline is attractive to seals.

PUPPING AREAS: All of the newborn pups we saw at Midway and on other atolls were on permanent islands or islets above high tide, or on sandspits only a few yards from permanent dry land. We did not see them on isolated, temporary sandspits which could be covered by high tides or washed away by storms, although these are regularly used as hauling grounds by adults.

ABUNDANCE

Two methods were used to estimate the size of the Hawaiian monk seal population: aerial surveys and ground counts.

We conducted aerial surveys of all the atolls on which seals are known to breed, with the exception of French Frigate Shoals. Counts for the latter atoll were made by Paul L. Breese, director of the Honolulu Zoo, and by POFI biologists. Our aerial counts were made from Navy UF-1 Grumman Albatross amphibians flying at a speed of about 120 knots and altitudes between 100 to 500 feet. In most cases, each of us made an independent count using a mechanical hand-tally. Usually we made at least two successive counts during each flight. The counts were sometimes checked against photographs taken simultaneously with a Fairchild F-56 camera. During any one flight, the differences between successive counts by the same observer, between different observers, and between the observers and the aerial photographs, were insignificant. Few of the seals on land were missed. Occasionally, a seal resting under the edge of a *Scaevola* thicket was difficult to see. Large green turtles (*Chelonia mydas*) basking on the beaches were momentarily confused with seals but caused little difficulty in making counts.

Ground counts were made on Midway and Kure atolls by walking entirely around the beaches of the larger islands and by landing on all of the sandspits and small islets.

The number of seals on land varies with the time of day and the season (Table 7 and Fig. 7). The best time for counting seems to be in afternoon during winter, when the most seals are on land. However, we had no way of knowing what fraction of the population was absent. Some individuals certainly were absent, as indicated by algae in the hair, mentioned elsewhere.

The population figures, by atolls, are presented in Table 4. The total prior to the pupping season is based on the highest counts of all seals during the winter of 1956–57, or else the highest counts of seals of age one year and older made during the spring of 1957. The total number of pups is based on the highest single count of pups, or on combined counts when it was evident, from age or location of pups, that different pups were counted. The total after the birth of the pups is the sum of the largest count of adults plus the total count of pups, and thus does not necessarily represent a single count. Because of the distances involved, we do not believe that the same seals were seen twice in widely separated atolls. Following is a brief description of the six atolls on which monk seals breed, and a listing of the dates on which we made counts of the seals.

Kure Atoll

The reef encloses a circular lagoon 6 miles across. Inside the southeast reef is Green Island, 1 mile long by ½ mile wide, largely covered with a dense growth of *Scaevola*. Several variable sandspits extend to the westward of the island for about 2 miles. Flights were made over Kure on December 9 (1100–1130), December 21 (0900–0930), February 12 (1430–1520), and May 14 (1355–1435). A ground count was made on June 5.

Midway Atoll

The lagoon at Midway is about 6 miles in diameter. Inside the southern part of the reef are two large islands. Sand Island, 2 miles long and 1 mile wide, is the site of a U. S. Naval Station. Eastern Island, 1¼ miles long by ¾ mile wide, is uninhabited except for a single Navy unit. Between the two islands are sev-

TABLE 4
HAWAIIAN MONK SEAL POPULATION IN SPRING, 1957

ATOLL	ADULTS AND SUBADULTS, WINTER, 1956 SPRING, 1957	DATE OF COUNT	PUPS BORN, SPRING, 1957	DATE OF COUNT, 1957	TOTAL POPULATION, SPRING, 1957
Kure Atoll	105	June 5, 1957	23	June 5	128
Midway Atoll	67	January 14, 1957	4	April 2	71
Pearl and Hermes Reef	257	December 17, 1956	33	April 15 May 14	290
Lisianski Island	241	April 15, 1957	15	April 15	256
Laysan Island	214	April 15, 1957	19	January 7 April 15 June 26[2]	233
French Frigate Shoals[1]	35	July 20, 1957	?	July 20	35
Total	919		94		1013

[1] Count by Paul Breese, Honolulu Zoo. A count of 30 seals was recorded in the scientists' log, April 24–May 12, 1957, cruise No. 59, M/V "Hugh M. Smith," POFI, U. S. Department of Interior, Fish and Wildlife Service.
[2] Partial count by David H. Woodside, Division of Fish and Game, Territory of Hawaii.

eral small islets and sandspits. On the east side of the lagoon, the reef-rock is about 5 feet above low tide level, exposing a 5-mile strip up to 15 yards in width, see map (Fig. 1). Aerial counts were made on December 9 (1415–1430), December 21 (1000–1130), January 7 (1345–1400), January 24 (1330–1400), February 12 (1600–1800), and May 14 (1630–1645). Complete ground counts were made on December 20, January 14, March 5, 14, 27, and May 2.

FIG. 1. Map of Midway Atoll.

Pearl and Hermes Reef

This atoll is roughly diamond shaped, 20 by 12 miles. There are three small islands (Kittery, Seal, and Grass) in the southwestern part of the lagoon. Seven to 12 fluctuating sandspits stretch eastward just inside the reef toward Southeast Island, the largest island in the atoll, which is about ½ mile long. In the northeast corner of the lagoon is North Island, with several sandbars immediately to the south. All the larger islets, except Kittery, are covered with low herbaceous vegetation. We made flights over Pearl and Hermes on December 9 (1245–1325), December 17 (1000–1100), January 7 (1300–1315), January 24 (1515–1545), April 15 (1550–1625), and May 14 (1520–1610).

Lisianski Island

This island is a coral "pancake," an atoll in which the lagoon has dried up entirely, leaving a depression in the interior of the island. The island is 1¼ miles long by ¾ mile wide. Reef formations surround the island, extending several miles to the southeast as Neva Shoal. We flew over Lisianski on January 7 (0930–0945) and April 15 (1250–1310).

Laysan Island

Laysan is a raised atoll in which the lagoon has no connection with the sea. The dimensions of the island are 1 by 2 miles, of the lagoon, ⅓ by 1 mile. It is surrounded by submerged coral reefs. We made aerial counts on January 7 (1100–1130) and April 15 (1405–1430). David Woodside camped on Laysan from June 25 to July 3.

French Frigate Shoals

This crescent-shaped atoll is 20 miles long by 6 miles wide. It contains about 12 permanent islets and several sandspits which occasionally shift position. The largest islet is occupied by a U. S. Coast Guard unit. Seal counts here were made by Paul Breese and by POFI scientists in 1956 and 1957.

From near extinction in the 19th century, the monk seal has increased slowly in numbers. In 1923, Alexander Wetmore visited all the islands and atolls in the Leeward Chain and estimated the total population at about 400 (Allen, 1942). Galtsoff counted 68 seals at Pearl and Hermes Reef in 1930 (Galtsoff, 1933). In 1951, the total population was placed at about 477, based on estimates made by Robert L. Sheehan on Kure, and Vernon E. Brock on all the other atolls (Bailey, 1952). In 1954, Johnson A. Neff and Philip A. DuMont made an aerial count of 334 seals on all the atolls except French Frigate Shoals. Biologists of POFI have made counts of seals during various cruises to all the Leeward Islands, except Kure, from 1950 to 1957. The total of their highest counts for each location is 589 seals. The 1957 total of 1,013 (Table 4) does not mean that there has been a recent and rapid population increase but that more intensive observations were made.

POPULATION FACTORS

Sex Ratio

The lack of obvious secondary sex characters makes it difficult to ascertain the sex of monk seals in the field. If a seal is not lying with the ventral surface exposed, it can usually be made to roll over on its side by poking it sharply with a stick. Thus, under field conditions, it is practicable to identify sex of only a small number of seals. Males are recognizable by the penile opening (Fig. 2). With practice, this cannot be confused with the less conspicuous umbilical scar on females. The females are recognizable by two pairs of teats.

JUVENILE SEX RATIO: Five pups were born in Midway Atoll in spring, 1957. Four were males; one prematurely-born pup found dead on the beach was a female. At Kure Atoll, we sexed 17 pups, of which 10 were males and 7 were females. At Laysan Island, on June 26 and 28, 1957, David Woodside tagged and sexed 23 young seals. Most of these were pups but a few were possibly yearlings. There were 8 males and 15 females. The foregoing counts total 22 males and 23 females.

SUBADULT SEX RATIO: Young seals of the yearling class and older examined at Midway and Kure atolls totaled 35, of which 21 were males and 14 females.

ADULT SEX RATIO: At Midway, seals were sexed whenever possible as groups (see Table 5) and individually. Total observations included 38 males and 31 females (single observations are not shown in Table 5). Unfortunately none of the above was marked and it is impossible to say how many were seen more than once. The largest single day's observation included 9 males and 3 females. In

TABLE 5
SEX RATIO OF ADULT HAWAIIAN MONK SEALS ON MIDWAY ATOLL[1]

DATE, 1957	MALES	FEMALES
January 14	5	5
February 2	5	2
March 5	9	3
March 14	4	2
May 2	6	3
Total observations[1]	29	15

[1] On each of 5 occasions when 6 to 12 seals were examined.

FIG. 2. Adult male monk seal, showing penile opening. When annoyed with a stick, a seal will usually roll on its side or back making definite recognition of sex possible. The distinct color difference along the side is not characteristic but is here the result primarily of the animal having rested on its belly. Midway Atoll, February 2, 1957 (KWK 53-3-9).

addition, 6 adults were tagged, 2 males, 3 females, and 1 unidentified.

On Green Island in Kure Atoll, we observed 11 adult males, 11 females with pups, 15 additional females without pups, and 16 adults of unknown sex. The observed sex ratio was strongly biased, of course, because of the large unsexed element and because animals with pups were obviously females. On the sandspits west of Green Island, Comdr. J. F. Reilly counted 8 females and 10 males. The total for Kure was 21 males and 34 females.

Among 154 seals of all age classes, in which sex was determined, were 75 males and 79 females.

Sex ratio data on adult and subadult seals must be interpreted with caution because of the possibility of differences in hauling-out habits of the two sexes.

Age at Sexual Maturity

Monk seal pups and presumed yearlings were first marked with metal tags in 1957. Therefore, no positive data on growth rates and age at which reproduction takes place will be available for several years. According to Bertram (1940), the Weddell seal normally bears her first pup late in her third year and some crabeater seals (*Lobodon carcinophagus*) give birth at the age of 2 years. According to Laws (1956*a*), the southern elephant seal usu-

ally produces her first pup when 3 years of age. Because of the several characteristics which monk seals share with the animals mentioned above and in view of the rapid growth rate observed in captive monk seals, it seems possible that the monk seal might participate in reproductive activity in the third year of life. All seals which we observed exhibiting sexual behavior, and all females which bore pups, were fully grown animals.

Reproductive Rate

The reproductive rate (number of pups born per 100 animals older than pups) of the Hawaiian monk seal seems to be unusually low when compared with that of other mammals. The total count of pups and the total count of older seals at each atoll are presented in Table 4. From these data, certain reproductive rates have been calculated for the following localities:

	PER CENT
Kure Atoll	21.9
Midway Atoll	7.5
Pearl and Hermes Reef	12.8
Lisianski Island	6.2
Laysan Island	8.9

The count at Lisianski was made quite early in the pupping season, that at Laysan was not complete, and when the last count was made at Pearl and Hermes Reef, probably only about 60 per cent of the pups had been born. Therefore, the actual reproductive rate at these localities was undoubtedly higher than the figures indicate. The June 5 ground count at Kure Atoll is the most reliable and important figure. Considering that the total population numbered 67, remarkably few pups (5 including one prematurely born) were seen at Midway in 1957. Furthermore, there were only 6 yearling seals, indicating a small pup crop in 1956 as well. Blasting operations in the ship channel and other human disturbances may have depressed the birth rate.

It is apparent that annually a large proportion of adult female monk seals fail to produce a pup. The walrus (*Odobenus rosmarus*) is the only pinniped known (with fair certainty) to breed in alternate years, a trait correlated with a lactation period exceeding 1 year (Brooks, 1954). Do missed pregnancies occur more frequently in monk seals than in other pinnipeds? The bearded seal (*Erignathus barbatus*) frequently misses a season between successive pregnancies (Chapsky and Kovalev, 1938). About 16 per cent of sexually mature female Weddell seals, and perhaps 20 per cent of sexually mature female crabeater seals, fail to become pregnant each year (Bertram, 1940). In a collection of 14 leopard seals (*Hydrurga leptonyx*), 21 per cent had missed pregnancy (Brown, 1957). Missed pregnancies occurred in 8 out of 66 sexually mature female southern elephant seals (Laws, 1956*b*). Several large samples of apparently mature female northern fur seals from the Pribilof Islands have been studied. Preliminary findings indicated that about 32 per cent fail to reproduce annually (Taylor, Fujinaga, and Wilke, 1955). Representing a sample of the commercial kill, 12,762 female fur seals, aged 4 years and older, were examined in 1956 and 1957. Of these, 46 per cent had missed pregnancy in the season studied (C. E. Abegglen and A. Y. Roppel, *in lit.*).

Age Groups

Pup and yearling monk seals are recognizable in the field by size. Between yearlings and adults, no distinct size classes were recognizable. Animals of intermediate size are lumped together as subadults.

Age group composition estimates at Kure Atoll and at Midway Atoll are presented in Table 6. It was not feasible to classify age groups other than pups during aerial counts. The following figures, therefore, are based on ground counts. The pup counts are the most accurate, as pups stay on land or in shallow water near shore where they are easily observed. Our observations indicate that subadults, and yearlings especially, do not haul out as frequently as do adults. Therefore, the

TABLE 6
ESTIMATED AGE GROUP COMPOSITION OF TWO POPULATIONS OF HAWAIIAN MONK SEAL

AGE GROUP	KURE ATOLL		MIDWAY ATOLL		TOTAL	
	Number	Per cent	Number	Per cent	Number	Per cent
Adults	79	62	53	75	132	66
Subadults (2+? years)	19	15	8	11	27	14
Yearlings	7	5	6	8	13	6
Pups	23	18	4	6	27	14
Total	128	100	71	100	199	100

counts of yearlings and subadults may be proportionately low. An unknown number of animals were doubtless at sea at both atolls.

Mortality

Little evidence of mortality among monk seals came to our attention. We found only one dead adult, on December 6, 1956. As no baculum could be found, it was probably a female. The occipital region of the skull was fractured. The only other dead seal we saw was a prematurely born female pup mentioned elsewhere.

On January 14, 1957, an adult with an infected penis was observed. Northern fur seals occasionally die as a result of similar infections.

Scars of various sizes are present on the bodies of all monk seals except nursing pups. Most are visible as dark lines through the hair, they range in length from about an inch to 2 feet. Most of these are probably made by contact with sharp coral. On December 20, a seal was observed with a large, open, fresh wound on its side. Of 67 seals seen at close range on January 14, 2 had arge areas of bare, dark-brown scar tissue on their sides (Fig. 3). It is surprising that an animal could survive such a wound. One adult was seen with half of the outer digit of the right hind flipper

FIG. 3. A large scar (partially hidden by the foreflipper), possibly inflicted by a shark, marks the side of this resting monk seal. Midway Atoll, January 14, 1957 (KWK 57-3-17).

missing. Large sharks which could inflict wounds of this nature are often seen in and around Midway Atoll. While the junior author was skin diving in Welles Harbor, Midway, watching the underwater swimming behavior of a seal, a school of 8 or 10 white-tipped sharks (*Triaenodon obesus*) was in the immediate vicinity. One of the sharks, about 4 feet long, and the seal swam within 4 feet of each other. Neither, however, showed the slightest alarm or concern.

During late May and June of 1956, Fish and Wildlife Service biologists of POFI made the following observations: "On Southeast Island [Pearl and Hermes Reef], a pair of adult seals was seen well up from the beach. The smaller of the pair was seriously wounded on the lower abdomen and right side. . . . On Whale Island [French Frigate Shoals], a young adult was found dead on the beach, apparently as a result of shark attacks. Most of the flesh was gone from the right side of the head and neck and the sides showed slashes typical of shark bites. At this island, a school of 20 to 25 three- to four-foot sharks was seen continuously milling about the shallow reef in the lee of the island." (E. C. Jones, FWS, *in lit.*)

We have not heard of killer whales (*Orcinus orca*) in waters around Midway.

The monk seal is able to increase and maintain its numbers in the Leeward Islands in spite of a low reproductive rate. The fact that 6 yearlings were marked at Midway and only 4 pups were born (plus 1 stillborn) there in 1957 may indicate that survival in the first year is unusually high. Nearly one-fifth of the fur seal pups born on the Pribilof Islands in recent years die before leaving the breeding grounds and an additional 50 per cent (approximately) die of natural causes before reaching their third birthday (Kenyon, Scheffer, and Chapman, 1954). It might be concluded that monk seals are fairly long lived and that mortality from disease and predation is relatively low.

MOVEMENTS

Marking

In order to follow the movements of individual seals, and to furnish a reservoir of animals of known source and age for future study, we tagged as many as possible (57). The tags were National Band and Tag Company size No. 19 monel metal cattle-ear tags. On one side was stamped a number preceded by "MS-"; the other side was stamped with "NOTIFY/F & W SERVICE/WASHINGTON 25 D.C." The tags were clinched on the web of the animal's hind flipper with special pliers designed for the purpose.

Pups, even weaned ones weighing up to 160 pounds, were easily tagged as they can be captured readily and held by hand. The yearlings were netted and firmly tied. In order to place tags on adults, the animals were quietly approached from the rear while they slept. The tag was then attached with a quick firm motion of the pliers. The seals always awoke with a violent thrashing motion that sent the pliers flying, but the tags usually clinched properly.

To facilitate recognition of individual seals at Midway, we attached to their tags strips of colored polyethylene plastic. We placed red strips on pups, yellow on yearlings, and blue on older animals. Each plastic strip was distinctively shaped (long, medium, or short; truncate, diagonal, pointed, or notched). Some of these were lost after about 1 month. These decorated tags were readily observed on sleeping seals. With binoculars, they aided identification by number on seals that were crawling towards or splashing into the water. It is often possible to approach a sleeping seal and read its tag number.

An attempt to mark seals by spraying them with quick-drying "Krylon" enamel was unsuccessful. The application of the paint awakened the seals and they crawled away into the water, the sand and water wiping off what little paint had got on to them before it dried. Fast drying paint (of the type used to mark highways) applied generously with a swab

should be successful for temporary markings (as it was found to be on the Alaska fur seal).

In Midway Atoll, we tagged 16 seals, including all of the pups (4), all of the yearlings (6), 3 subadults, and 3 adults. These represented about 23 per cent of the total Midway population. At Kure Atoll, we tagged 1 yearling and 15 pups, or 65 per cent of the pups born during the 1957 season. At Laysan Island, David Woodside tagged 25 seals, the majority being pups, possibly a few yearlings, 1 adult female and 1 subadult female. For the convenience of future workers, the series are listed: Midway, MS-1 to MS-16; Kure, MS-17 to MS-32; Laysan, MS-51 to MS-75.

Home Range

SIZE: With the exception of mothers with nursing pups, it is apparent that each seal ranges widely in Midway Atoll. Of the 16 seals tagged at Midway, 10 were subsequently seen a total of 22 times, exclusive of repeat observations on nursing pups (Table 7). The observations of tagged animals reveal that individual seals do not habitually haul out at the same place. Rather, there are a number of favored hauling grounds which most of the seals use at one time or another. These regularly-used hauling grounds are several small permanent islets (Seal Island, Rocky Island, and Dynamite Island) plus one to three shifting sandspits which lie between Sand Island and Eastern Island. The south and east shores of Eastern Island are also frequented by seals. On Sand Island, with its many human inhabitants, seals occasionally haul out on Picket Point and Frigate Point. Particularly during the summer, a number of seals were seen hauled out on the flat rocks of "Five-mile Reef." The entire seal population in Midway Atoll seems to share a common home range which includes most of the lagoon, or at least its southern and eastern halves.

TABLE 7
MOVEMENTS OF TAGGED HAWAIIAN MONK SEALS IN MIDWAY ATOLL, 1957
(Repeats of unweaned pups excluded)

TAG NO.	AGE	SEX	TAGGED		OBSERVED		DISTANCE MOVED SINCE PREVIOUS OBSERVATION
			Date	Locality	Date	Locality	
MS-1	yrl	♀	March 5	Seal I.	March 14	Seal I.	50 yards
					March 18	Sand I.	0.5 mile
MS-2	ad	♂	March 5	Seal I.	April 5	Eastern I.	1.25 miles
MS-4	yrl	♀	March 5	Dynamite I.	March 27	Seal I.	0.6 mile
MS-5	yrl	♀	March 5	Dynamite I.	March 14	Rocky I.	300 yards
MS-7	ad	♀	March 5	Rocky I.	May 2	Rocky I.	10 yards
					June 4	Eastern I.	1.3 miles
MS-8	yrl	♂	March 22	Eastern I.	March 24	Eastern I.	50 yards
MS-9	pup	♂	March 27	Dynamite I.	May 27	Eastern I.	1.0 mile
					May 31	Eastern I.	100 yards
					June 4	Eastern I.	100 yards
					October 11	Dynamite I.	1.0 mile
MS-10	pup	♂	March 27	Dynamite I.	May 13	Eastern I.	0.5 mile
					May 27	Eastern I.	0.25 mile
					May 31	Eastern I.	100 yards
					June 3	Eastern I.	100 yards
					August 26	Eastern I.	1.0 mile
MS-12	pup	♂	April 2	Eastern I.	May 13	Eastern I.	1.0 mile
					May 18	Eastern I.	1.0 mile
					May 29	Eastern I.	100 yards
MS-14	ad	♂	May 2	East Sandspit	May 4	Eastern I.	0.5 mile
					May 8	Eastern I.	0.25 mile

TRAILS: The shade of *Scaevola* shrubs is attractive to seals (see Fig. 4). In order to reach the thickets, the seals must often crawl up the sloping sand beach, then up an embankment of solidly packed coral rubble a foot or two high. Certain favorite routes are habitually used and grooves, or trails, are worn in the sand and hard steep banks. These are visible from the air and during aerial counting help to locate seals lying partially hidden beyond the beach line (Fig. 5). On Rocky Island, the only small islet in Midway Atoll with vegetation, a number of seals use the same trails and resting places. Whether certain trails and resting places along less frequented beaches are used by certain individuals or by a number of seals was not ascertained.

WALLOWS: While resting on coral sand beaches, monk seals roll and root to form depressions about 6 inches deep. When digging such a depression, the nostrils are closed and the muzzle is pushed into the sand as the seal forces itself forward with its foreflippers (Fig. 6). In this way, the head becomes partially buried and a ridge of sand is pushed up, rising to eye level or above. During such rooting and rolling, the eyes often become caked with sand and mucus. The eyes of one seal, seen sleeping, were so caked with sand that the lids could be only partially closed. This animal and others, seen sleeping with lesser amounts of sand sticking to the cornea, appear oblivious of any discomfort. When seen from the air, sand wallows are quite evident on beaches frequented by monk seals.

FIG. 4. Large adult female. Monk seals often retreat to the shade of *Scaevola* shrubs above the beach line. Kure Atoll, June 5, 1957 (KWK 57-16-34).

Daily Cycle of Activity

Very few seals may be seen on land early in the morning. Generally, as the day advances, an increasing number of seals haul out. About noon, or throughout the afternoon, the number on land reaches a maximum. Just before sunset, there is a drop in number on land. This is partially illustrated by the number of seals observed on the regular boat runs between Sand and Eastern islands. Table 8 presents the average number observed during 57 trips. We were unable to make comparable counts at sunset or shortly thereafter when seals were leaving the hauling grounds.

For this and other reasons (see food habits), it may be presumed that monk seals are nocturnal, or at least crepuscular, feeders. Nevertheless, swimming and feeding seals may be seen in the water all during the day.

Seasonal Movements

At Midway we have noticed a marked seasonal variation in the number of seals hauled out on the islets and sandspits between Sand and Eastern islands. In November and early December few seals hauled out. In late December, coincident with the beginning of the winter storm period, they increased markedly. About March, when calm summer weather began to prevail, the number dropped and by June very few were seen. Figure 7 shows the seasonal variation in six aerial counts, in six ground counts made when we landed on all of the islets and sandspits, and in the highest

FIG. 5. Trails and wallows as seen from the air aid in locating seals partially hidden among sand dunes and *Scaevola* clumps. Characteristically, seals are grouped near points of sand as shown here. Laysan Island, January 7, 1957 (KWK 57-1-17).

counts made on 49 days during the regular boat runs to and from Eastern Island.

The number of seals counted on land depended on the total area observed. The largest counts were made from aircraft, intermediate counts from land, and the smallest counts from the boat. The relative number of seals counted by the three methods indicated that the sample area observed from the boat was a reliable index of the abundance of seals on land in Midway Atoll. The monthly mean of boat counts is shown by a solid line in Figure 7 to indicate the general trend of seasonal abundance on land.

We suggest two possible explanations for the variation: (1) the seals spend more time in the water during summer because of high air temperatures, and (2) the seals move out onto the unprotected reef during the calm summer season. We have some evidence to support the latter hypothesis. In five flights over "Five-mile Reef," from December 9 to February 12, we observed no seals hauled out on the reef. On March 27 we visited the reef in a small boat and counted 11 seals. On May 13 we cruised outside the reef in a tugboat and saw 13 seals lying on the exposed reef rock. Probably each of the above factors is partly responsible for the disappearance in summer of seals from their winter hauling grounds.

The yearling seals present an interesting

FIG. 6. Monk seals, while lying on beaches, push their noses into the sand to form shallow wallows. Such behavior may help the animals to keep cool and afford some protection from flies. Midway Atoll, February 2, 1957 (KWK 57-19-7).

problem. We saw the first yearlings[1] on December 20. After that, we saw yearlings regularly throughout the winter. In the spring, we tagged six of them, apparently the entire year-class at Midway. One yearling was observed on March 27, after which none were found. When first seen on land, all yearlings had noticeably more algae on their hair than adults. This suggests that yearlings spend more time in the water during the summer. A similar situation seems to exist among the Weddell and crabeater seals (Bertram, 1940) and elephant seals (Bartholomew, 1952).

There is no evidence that monk seals migrate regularly. Of their wanderings at sea, we know very little.

FOOD HABITS

In the Wild

The regurgitated stomach contents from a seal resting on a Midway beach were collected, as was the stomach of BDM 490. The stomach contents were identified by Donald W. Strasburg and other Fish and Wildlife Service biologists at POFI headquarters in Honolulu (see Table 9). Previously no food items from Hawaiian monk seals had been identified. However, Munro (1942) stated that the stomach of a seal he killed contained half-digested fish.

The limited available material indicates that eels, which are numerous in atolls, and cephalopods comprise the major food taken by monk seals and that their food consists primarily of bottom inhabiting forms. It was not possible to determine whether the cephalopod remains (beaks and eye lenses) came from squid or octopus. Since the squid is largely pelagic and the octopus is a bottom form, the latter is more probable.

It might be deduced that the monk seal is primarily a night feeder. Conger eels remain buried in the sand during daylight. At night moray eels emerge from crevices in reefs to hunt for food and Strasburg saw conger eels with their heads and parts of their bodies protruding from the sand at night. Cephalopods are also nocturnal feeders. It was observed that, in general, few monk seals were on beaches in early morning hours; but that during the day, their numbers there increased (Table 8). While camped on Laysan Island in late June, 1957, David H. Woodside (*in lit.*) observed, "I noted a few seals feeding in shallow water at night . . . . Their actions were very slow and deliberate as if they were after something stationary."

FECES: Fecal deposits are often seen on the beaches where the seals haul out. In general, the fecal matter is quite liquid but occasionally it is in lumps of claylike consistency. The color ranges from brilliant orange and ocher

TABLE 8
HOURLY VARIATION IN THE NUMBER OF SEALS HAULED OUT AT MIDWAY

NUMBER OF COUNTS	TIME OF COUNTS	MEAN NUMBER OF SEALS ON LAND
26	0800	14
13	1200	25
18	1730	29

[1]Animals born in the spring of 1956.

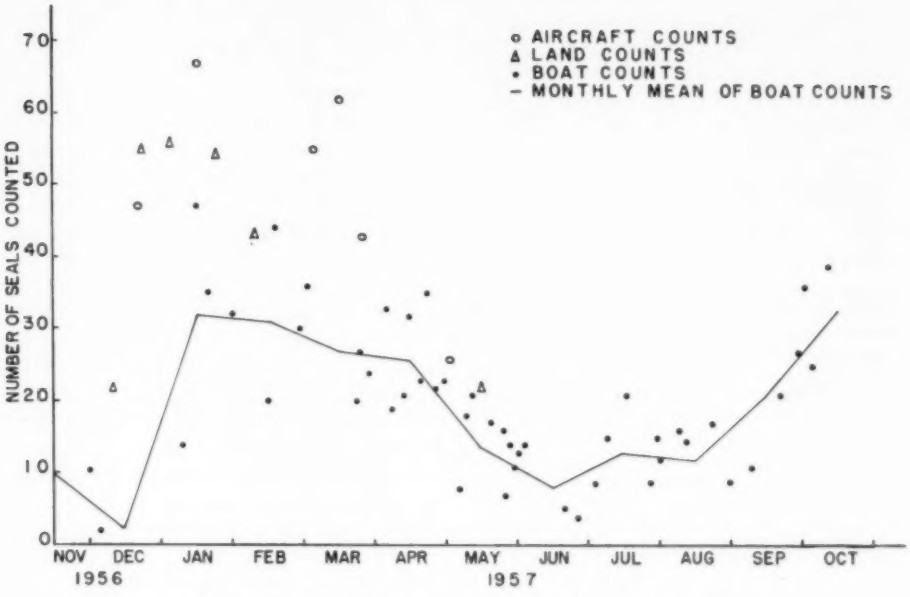

FIG. 7. Counts of seals, Midway Atoll, November, 1956–October, 1957.

yellow to whitish gray, brown, and purplish black. No hard parts of food items were observed in feces.

In Captivity

Two monk seals held captive in the Waikiki Aquarium showed a preference for eels. However, because other fish were less expensive and easier to obtain, the animals were usually fed smelt (*Osmerus mordax*) and California horse mackerel (*Trachurus symmetricus*) from California. The female ate both smelt and mackerel while the male preferred mackerel. Together, the two seals consumed about 25 pounds of fish per day, roughly one-seventeenth of the body weight. When living fish were placed in their pool, the seals showed a preference for them. All-purpose vitamin B capsules were placed in fish and fed to the animals daily (S. W. Tinker and K. A. Wong, *in lit.*). A captive Mediterranean monk seal was said to prefer eels over other fish and consumed about 14 pounds of fish daily (King, 1956).

BEHAVIOR

Locomotion

While swimming slowly in shallow water near shore, forward motion is attained primarily with the foreflippers. However, when more speed is desired, the hind flippers and posterior part of the body undulate laterally as in other phocids. The foreflippers were seen to be in strong rapid motion through a vertical plane perpendicular to the body axis while seals were swimming rapidly in clear water over a white coral sand bottom. It appeared to us that the foreflippers were being used to increase speed as well as to steer.

While skin diving, the junior author has observed four seals swimming under water at close range. Two of these were kept under observation for a considerable time. Although the lateral undulations of the body trunk and

TABLE 9
FOOD OF TWO HAWAIIAN MONK SEALS

FOOD SPECIES	STOMACH CONTENTS BDM 490 VOLUME 100 CC.		SPEWING VOLUME 440 CC.	
	Number items	Per cent volume	Number items	Per cent volume
Conger eel (*Ariosoma bowersi*)	2	2	9	60
Moray eel (*Gymnothorax* sp.)	—	—	4	35
(*Echidna* sp.)	5?	3	—	—
Flatfish (*Bothus mancus*)	—	—	2	1
(*Bothus pantherinus*)	—	—	1	1
Scorpenid (*Scorpaenopsis gibbosa?*)	—	—	1	1
Larval fish (*Surgeon fish?*)	—	—	1	1
Squid or octopus (*Cephalopod*)	3	95	2	1

the vertically held hind flippers obviously furnished the chief means of propulsion, the foreflippers were in almost continuous motion. For only a few seconds, one seal was observed to hold the foreflippers motionless, when it trailed them back and down at an angle of about 45° from the body.

Regular and energetic use of the foreflippers for swimming appears to be unusual among phocids.

Progression by dorsoventral undulatory movements of monk seals on land is in every respect similar to other phocids (Fig. 18).

Vocalization

Sounds produced by monk seals fall into two categories: "bubbling" sounds and "bellowing" sounds.

BUBBLING SOUNDS: When a sleeping seal is awakened, it usually utters a rapid series of soft bubbling sounds which originate deep in the throat: "bgg-bgg-bgg-bgg-bgg." The sound is audible under usual circumstances to a distance of about 50 feet. It is similar to the sound made as water flows from an inverted jug. To some observers, it sounds like a rapid series of belches. This sound appears to denote mild alarm. If the seal is not annoyed but approached closely, the mouth is kept closed while the sound is made. If the seal is touched, it opens its mouth in threat attitude while continuing to utter this sound. Weddell seals apparently make a similar sound (Bertram, 1940).

BELLOWING SOUNDS: When one seal is threatening another, when a mother is defending her pup, or when a seal's route to the water is blocked, several basically similar sounds are uttered, perhaps best described as a grunting bawl. Sometimes a blast of air is expelled simultaneously, forming a snort or snorting bellow. A mother defending her young from an intruder utters a louder version, best described as a bellow—"mrrraugh." The sound is very similar to that made by female northern sea lions (*Eumetopias jubata*). In general, the pup may be said to bleat—"mwaa-mwaa-mwaa." Except for its lesser strength and volume, and higher pitch, the sound resembles the bellow of the adult. When the mother is displaying affection toward her pup, she utters a hoarse throaty growl or moan, a modification of the bellow, to which the pup responds by bleating. When disturbed, the pup utters a diminutive version of the grunting bawl, an explosive "aaah" or "gaah."

Escape Reactions

The fearless nature of Hawaiian monk seals is similar to that of other marine mammals which have evolved and remained in remote oceanic areas. Terrestrial predators are unknown. Human populations have invaded only in recent times, and permanent settlements exist only on two of the six atolls where the seals breed. In some respects, the behavior of the monk seals is similar to that of the fur seals (*Callorhinus* and *Arctocephalus*) and certain antarctic phocids which breed in isolated regions. It is quite unlike that of the

northern phocids and sea lions (*Eumetopias* and *Zalophus*) which, in areas disturbed by man, quickly learn to avoid him.

Although adult monk seals resting singly on a beach can be easily approached, a large group usually takes to the water. Seals that awaken bump others as they begin to move and the result is a general alarm ending in a stampede. Yearlings, however, are not easily aroused and even after adults around them have made a hurried departure, these young animals may be left sleeping or languidly eyeing the intruder. Adults, if not disturbed, may quickly become accustomed to human presence. For six hours, four seals basked near us while we were working on a dead specimen. When we first arrived, these animals displayed mild alarm; before we departed, they ignored us even when we walked within 3 or 4 feet of them. Although seals are often poked at with sticks by people walking Midway's beaches and are sometimes annoyed by dogs, they remain surprisingly unwary. However, it may be significant that seals are found less frequently on the beaches most used by people. Seals only occasionally now haul out on the beaches of Sand Island where a large human population has been present for several years. They are regularly found on Eastern Island, and two pups were born there in 1957. Only about a dozen men occupy this island. We found that anyone who found a seal on a beach invariably drove it into the water. However, the Navy protects the seals from actual physical violence. By far the greatest number of seals haul out on the small islets and sandspits between Sand and Eastern islands.

Threat Display

Although a mother with a pup will charge with open mouth and bellow at human approach, the aggressive behavior is primarily a threat display rather than an attack. We failed to hold our ground in the face of such charges until a bite was possible. Generally, we have found it difficult to induce a charging seal to grasp a stick held near its mouth. In one instance, however, our field notes in a manila folder were snatched from our hands, shaken violently and tossed aside by a mother seal defending her pup. This defense behavior is in marked contrast to that of northern fur seals. When a stick is presented to one of these animals under similar circumstances, it is invariably seized with the teeth. A man who failed to escape in the face of such a charge was severely bitten (Kenyon, 1957).

The threat display is also exhibited underwater. On July 20, 1957, while skin diving just inside the southwest reef at Midway, Richard T. Takahashi and the junior author cornered an adult female seal in a small deep hole about 10 by 15 feet, surrounded by high coral formations on three sides. After milling about in the hole for a minute or two, the seal started past us towards deeper water. We swam over to block her escape; we were at a depth of about 5 feet. When we got within 6 feet of the seal, on a course convergent with hers, she turned and came directly towards us with her mouth open in typical threat display. Her head was raised slightly above the axis of her body. When she was a yard from us, she swerved and made a break for the deeper water. She made no audible sounds underwater.

Play

On several occasions, adult seals pulled themselves on to sandbars covered by less than a foot of water. Here they would roll from one side to the other, waving their flippers in the air, apparently in play.

A two-month-old pup, after we awakened it at the water's edge on Eastern Island, romped and rolled in the shallow water near the beach; then as we walked along the shore, it followed along beside us for about a quarter of a mile. Frequently it raised its head to watch us, then returned to its frolicking. After about 10–15 minutes, it returned to the place of its birth on Dynamite Island, hauled out and went to sleep.

Nonreproductive Social Behavior

Monk seals appear to have no fixed social organization. Although aggregations of 2–3 to as many as 36 were seen hauled out on Midway beaches, the animals paid little attention to each other. Lone animals are frequently seen. At the end of the trails leading up into the *Scaevola* scrub, we seldom found more than one seal. When hauled out on sandspits or small islands in lagoons, it appears that the aggregations result more from a desire to rest on a favorable spot than from a gregarious tendency. Hostility between individuals was not observed except during sexual behavior.

Several times, however, it was noted that the presence of one seal appeared to stimulate another to haul out near it. For example, we visited the western point of Eastern Island frequently and no seals were seen there. Shortly after two mothers chose this point on which to bear their pups, we observed two other seals haul out to sleep in their general vicinity.

The Hawaiian monk seals are not thigmotactic as are northern elephant seals (*Mirounga angustirostris*) (Bartholomew, 1952) and most otariids. If a sleeping seal is touched, however lightly, it immediately awakens with a start. If the cause of its disturbance is another seal, it simply rolls or crawls a short distance and goes back to sleep. Monk seals were never observed lying in contact with one another.

When seen in the water during the nonreproductive period, seals were generally alone. When two or more individuals were seen together, it appeared to be because of their proximity to a favorite sandspit. When groups were startled into the water, each seal went its own way and the group quickly dispersed. Only once, on November 29, 1956, did we observe adults, not sexually excited, swimming in close company. On this occasion, three seals were swimming about 40 yards offshore. One soon left and the other two rolled leisurely on their backs and frequently raised their heads to look at us.

Reproductive Behavior

Field observation of sexual behavior in the monk seal is hampered by lack of obvious sexual dimorphism. Adult males are darker than most females. Females usually appear larger and fatter than males. In many of the observations which we interpreted as sexual behavior, the sex of the animals was not verified by observation of the external genitalia. Copulation was not observed; undoubtedly, as in most phocids, it takes place in the water. Seals which appeared to be pairs engaged in sexual behavior were observed on numerous occasions from March 5 to July 8.

Several times we observed seals (apparently males) approach females with pups. In every case, the female displayed threat behavior and the approacher was repulsed. Solitary males swimming near beaches occupied by females with pups showed considerable interest while still some distance away. On April 14, a male hauled out directly in front of a mother and pup, his head raised and appearing alert. He was quickly repulsed, whereupon he swam to another female and pup about 100 yards down the beach. Although one of us was standing only a few feet away, he hauled out. Without raising her head, the female snorted and the male backed into the water, leaving the vicinity.

The sense of smell may aid males searching for females. On April 17, we observed a male about 100 yards offshore suddenly stop, raise his head and gaze at a female directly up wind from him. Holding his head high above the water, he then swam rapidly and directly toward her, hauling out in front of her. The female reared, snorted, and threatened, to which the male responded in a similar way. Although open-mouthed sparring continued for several seconds at close quarters, the animals did not bite each other. The male then backed hurriedly into the water, glancing several times at the female as he swam away.

On April 2, when a female on the beach without a pup was approached by a male as

described above, he was threatened but not driven away. Before approaching the female, the male uttered several rolling bellows, sometimes ending in a snort. Repeatedly, the male nosed the abdominal region of the female, which caused her to threaten, and the male repeated the rolling bellow. He then lay with his head near her abdomen and his body at right angles to hers.

Pairs of animals in the position described above, were frequently seen lying dormant for long periods on the beaches. Occasionally, the male would sniff and nip at the female's genital and abdominal region. If, as frequently happened, this caused the female to attempt escape, the male attempted to stop her by following closely and gently biting at her abdominal region. An occasional hard nip precipitated bluffing bouts. If the female entered the water the male pursued her. The male sometimes chased the female quite rapidly, swimming high in the water with head raised and leaving a conspicuous wake. During such a chase, the male might utter coughing snorts repeatedly. In the water, the female sometimes put on a display wherein she beat the water with her flippers. On one occasion, a female lay on her side in very shallow water waving her hind flippers in the air and beating up a spray. She later beat the water with a foreflipper. The male, in the meantime, was beside her, facing her, uttering coughing snorts. On another occasion, a male was seen in the water beside a female; she rolled on her side and thrashed the water with a foreflipper. This was followed by both animals rearing up, facing each other and bluffing with open-mouthed threat displays. Finally, the female turned and swam away, the male following, both swimming with head and shoulders high in the water. On June 5, a female drove a courting male from her vicinity (Fig. 8).

No marked hostility between males was observed during the breeding season. Males which are with females seem to pay little attention to other seals as long as they do not approach closely. On March 27 we landed on a small sandspit where 17 seals, including a courting pair, were hauled out. All of the seals entered the water, the pair remaining together. While they were in the water, a third seal attempted to follow the female, but the male threatened him with raised head and open jaws, uttering coughing snorts. When we left the sandspit, the pair immediately hauled out, the male appearing to guide the female onto the sand as he remained close to her. The third seal attempted to haul out at the same place but was again repulsed and moved to another area. This animal made no hostile display.

FIG. 8*a*. A courting male frolicked about a reluctant female.

On two occasions when we approached pairs of seals, whose sex was positively identified, the male took to the water; but when we prevented the female from leaving, the male hauled out again, giving threat display

FIG. 8*b*. The female threatened the male, bellowing and charging with open mouth. The male quickly left the vicinity. Kure Atoll, June 5, 1957 (KWK 57-18-2 and 3).

toward us. Such behavior contrasted strongly with that of males not exhibiting sexual behavior.

Captive Animals

Mr. Spencer Tinker (*in lit.*) contributed observations on three monk seals, each of which he has kept in captivity at the Waikiki Aquarium for more than a year. Two seals, a male and female, were subadult and no breeding activity was observed.

The seals were playful and showed considerable tameness but would not allow themselves to be touched. While cleaning the pool, attendants were occasionally "nipped in the pants and on the leg" by the seals as they played nearby. The animals often played "for hours in mock battles and gentle wrestling." They also played with objects such as bits of rope, rubber balls, and pieces of wood which spectators dropped into their pool.

Their response to the presence of other animals in the pool varied considerably. They got along well with harbor seals (*Phoca vitulina*). The two species never fought. However, at feeding time, the harbor seals hung back and gave way to the monk seals. Sea turtles (*Chelonia mydas*) in the pool were persistently annoyed by the monk seals which would grasp the turtles' hind flippers in their teeth. The turtles were removed when their hind flippers became shredded by the seals' teeth. A hawks-bill turtle (*Eretmochelys imbricata*), however, would pinch the seals on the belly and the seals, in general, avoided it. During an encounter, this turtle was bitten by a seal and blinded. A 5-foot bottom-living species of shark was relentlessly pursued by the seals. Eventually, the shark was exhausted and a seal dragged it backwards through the water by the tail. When a small pilot whale (*Globicephala*) was placed in the pool, the seals were terrified, but in a few days "they were around it, smelling and rubbing it with their noses." In general, the seals appeared more nocturnal than diurnal. They spent most of the night in the water and would rest for many hours on an island in the pool during the day.

BIRTH AND DEVELOPMENT OF YOUNG

Pupping Season

Pups are born from about the first of the year until at least the end of June. Most are apparently born from mid-March through May.

In 1957, the first pup was seen from the air on a Laysan Island beach on January 7. The earliest authentic birth date we can find for Midway Atoll is March 22, 1956. At 0900 on that date, J. E. Graves (*in lit.*) of Honolulu saw a newly born pup on the west tip of Eastern Island. "The pup was still wet and the fetal membranes were attached. It had probably been born less than an hour." Bailey (1952) recorded a newly born pup on Pearl and Hermes Reef in late December, 1912, and that on March 15, 1913, 20 females with pups were seen at Pearl and Hermes Reef.

During the spring of 1957, five pups were born at Midway. The first, a premature 9-pound female, was found dead February 27 on the beach at Eastern Island. Birth dates at Midway in 1957:

February 20 (est.)	1 female
March 24	2 males
April 2	2 males

On June 5, 1957, 19 pups were examined on the beaches of Green Island, Kure Atoll. One had been born the morning of our arrival. The weights of the others were estimated and their approximate birth dates, all in 1957, calculated by reference to known growth and molt rates:

	NUMBER BORN
April 10–20	1
April 21–30	7
May 1–10	3
May 11–20	3
May 21–30	2
May 31–June 5	3

Only one large female that could have been pregnant was seen. This indicates to us that the pupping season was virtually complete at Kure by June 5. The possibility exists that other pregnant females were at sea.

It is interesting to note that the pupping seasons of other monk seals differ from that of the Hawaiian seal. The Mediterranean species is said to pup during September and October (King, 1956) and the Caribbean species in early December (Ward, 1887).

Birth

The four pups born alive at Midway were born either at night or early in the morning. New pups were found in the morning where none had been seen the night before. On Kure, a newly born pup was found on the beach at 0900.

At birth, the monk seal pup is thin, but not as thin as the elephant seal pup (Bartholomew, 1952). The fetal membranes had been detached from three pups seen a few hours after birth. The still bloody, damp tissues lay on the coral sand nearby. We found no clue as to how the umbilical cord was parted so soon after birth. Young fur seals may trail the placenta from the umbilicus for several days after birth. A captive sea lion broke the umbilicus from her pup by jerking the placenta with her teeth (Slijper, 1956). The newly born monk seal is wide-eyed (eye color, blue-black) and apparently is able to see quite well. It is toothless (see dentition) and has a well-developed single coat of soft black hair (see pelage). Like other pinnipeds, it moves about with surprising agility soon after it is born.

Nursing and Weaning

The mother monk seal nurses her pup from four abdominal nipples, which are extruded only when the pup is nursing. The bearded seal (*Erignathus barbatus*) (Mohr, 1952) and the monk seal are apparently the only phocids having four functional teats.

During the nursing period, the mother remains constantly near her pup. She rolls on her side to permit the pup to nurse (Fig. 9). During the first 30 to 40 days of its life, the pup normally nurses at frequent intervals (several timed at 4 to 5 minutes) and gains weight rapidly (see growth). When not nursing or swimming, the pup sleeps beside its mother. When sleeping, the pup sprawls flat

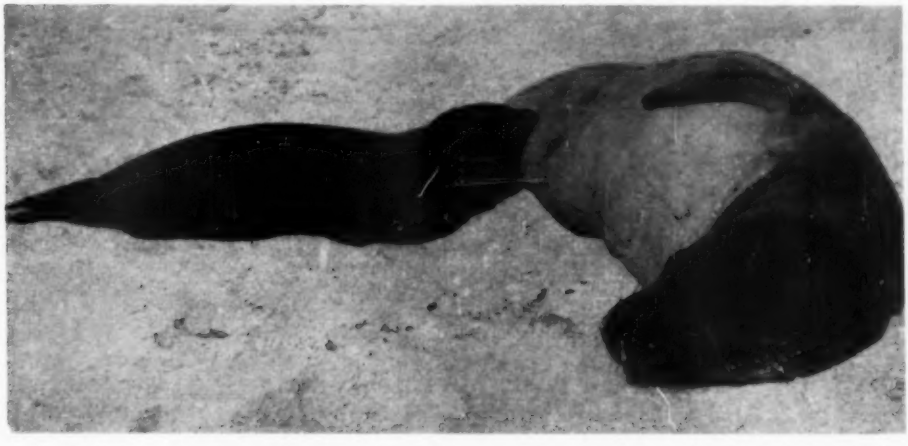

FIG. 9. A 12-day-old male monk seal pup nurses from one of its mother's four abdominal nipples. Nursing seals usually ignore human observers unless approached more closely than 8–10 feet. Midway Atoll, April 14, 1957 (KWK 57-16-9).

on its belly or rolls over and lies on its back (Fig. 10). The latter position seems to be a favorite one.

When the mother seal comes ashore to give birth, she is usually enormously fat (Fig. 11). As the nursing period approaches its end, the mother becomes quite gaunt. When she bends her body, huge wrinkles appear. While mothers were swimming with their pups we watched closely but saw no indication that they were attempting to find food. We found no indications that the mothers left their pups at night to feed. Near the beach camp of David Woodside on Laysan Island in late June, 1957, a nursing mother remained ashore with her pup during the night. We conclude from these observations that the mother fasts during the entire nursing period.

The maximum observed nursing period was 37 days. We would judge that the average pup is weaned in about 5 weeks at a weight of about 133 pounds (see growth).

The mother of pup MS-12, less fat than other mothers when her pup was born, nursed it for only 20 days and deserted it when it weighed only 82 pounds, somewhat more than half the more usual or apparently normal weaning weight. Pup MS-12 survived for at least 27 days after being deserted, but whether it ultimately survived, we do not know, since it disappeared from its usual hauling-out places.

Since the pup's instinct to follow its mother is strong, we presume that the mother, after her supply of milk has been exhausted, slips away and deserts her pup while it is sleeping. This was the case when the mother deserted MS-12. Mother and pup were seen sleeping on the beach at 0800. By noon when we visited the area, we found the sleeping pup alone and the mother was not subsequently seen.

After it is deserted by its mother, the pup remains near the location of its birth. Pup MS-10 was frequently observed as it played in the water or slept near its birth site until it was 50 days old, when it was found sleeping about a half-mile away. After this it was occasionally seen at various places along the shore of Eastern Island over a mile from its birth place.

Swimming

The pup is able to swim at birth. When pup MS-12 was taken from its mother for tagging

FIG. 10. A monk seal pup, satiated after a nursing period, sleeps on its back. After approximately 3 weeks of supplying milk for her pup, the mother here shows considerable loss of weight. Light hair, an indication of the postnatal molt, is visible on the pup's muzzle. Midway Atoll, April 22, 1957 (KWK 57-16-3).

FIG. 11. The mother monk seal characteristically attempts to keep her newly born pup under her muzzle or behind her when closely approached. The extreme obesity of the female at parturition is illustrated. Kure Atoll, June 5, 1957 (KWK 57-18-30).

and weighing on the day of its birth, it was moved down the beach parallel to the water for about 50 yards. By the time we had finished with it, its bellowing mother had joined it. She immediately led the pup to the water and both swam slowly along the beach until opposite the place of birth. Here the mother hauled out and led the pup to the spot from which we had removed it. The pup swam weakly, head high, and mainly with its front flippers.

Mother and pup usually remain on the beach for the first few days. The first time we saw a mother in the water (under undisturbed conditions) with her pup was the fourth day after birth. From this time, she spends short periods during the day swimming along the shore, closely followed by her pup, after which the two return to the general area where the pup was born. The mother spends much time on the beach where she lies facing the water while her pup frolics a yard or two

away in the shallows. As weaning approaches, mother and pup spend more time in the water and may go 100–200 yards from the beach.

Recognition of Pups by Mothers

When mother and pup are disturbed by humans, or when they are crawling along the beach, they keep in contact by a continuous series of calls, the mother bellowing and the pup bleating. When a pup is out of sight of its mother, she locates it by its bleating and crawls in the direction of the sound.

On May 4, when pups MS-12 and MS-13 were 33 days old and after MS-12 had been deserted by its mother, both pups were taken to a common location for weighing. As usual, the mother of MS-13 followed. After weighing MS-12, we released it on the beach, and then carried MS-13 behind a dune out of sight of its mother, so that she would not interfere with the weighing. When the mother of MS-13 noticed her pup was gone, she looked about and immediately noticed pup MS-12, which was bleating. She crawled rapidly to it, sniffed it several times, then turned away and continued her search for her own pup, indicating that a mother recognizes her pup by smell.

A few minutes later pup MS-12 approached MS-13's mother and tried to nurse. She did not at first object. However, when her own pup was returned, she became confused and very excited. She lunged at and bit both pups. A brief interval of bleating, bellowing turmoil followed. The mother bit both pups several more times and grasping them in her teeth she attempted to toss them both away from her. Pup MS-12 soon became discouraged and hastened to leave. Pup MS-13 continued to approach his mother's face, but still confused, she bit at him and he angrily bit back at her. The mother then proceeded toward the water, her pup following. Exhausted by the exertion, she soon stopped, and when her pup approached bleating, she nuzzled and accepted it. Within five minutes, she was nursing her pup and MS-12 was not seen to approach her again.

Care and Defense of Young

The mother monk seal shows considerable affection toward her young. The pup often rubs and nuzzles its mother's head and neck, and the mother sniffs and nuzzles her pup in an affectionate way. When a bleating, frightened pup is allowed to return to its mother, she usually places her head and neck over it protectively (Fig. 11), and the bleats of the pup are answered by deep moaning sounds from the mother. This behavior is in marked contrast to that of the Alaska fur seal mother which, other than to nurse it, shows little regard for her pup. Rarely, and only within a few hours after birth, a mother fur seal will remain near her pup or attempt to drag it with her when she is frightened and other animals are departing.

From the time her pup is born until she deserts it, the mother monk seal normally remains aggressive toward humans and other seals, except toward other nursing females with whom she is loosely associated. In order to tag and to obtain weights and measurements of pups, it was necessary for one of us to divert the mother while the other made off with the pup.

On the day that pup MS-13 was born, it was taken from its mother for tagging and weighing. While one of us diverted the mother, the other dragged the pup behind a sand dune. The mother, occupied with her tormentor, failed to miss her pup until it was beyond her range of vision. When she missed it she first dashed toward the water, looking frantically about. Seeing no sign of her pup there, she turned rapidly about in several circles, constantly peering behind her and bellowing. Soon she heard the bleating of her pup and proceeded in the direction of the sound. This mother remained unusually aggressive in protecting her pup until shortly before deserting it at the end of the nearly 6-week nursing period.

On one occasion, we were weighing pup MS-12 recently deserted by its mother. Pup MS-13 and his mother were more than 100 yards away in the lagoon. Hearing the bleating of MS-12, the mother of MS-13 swam rapidly toward us, head raised and bellowing, her pup following closely behind. She continued her charge onto the beach for 10 feet or more, to within about 2 yards of us.

On another occasion, when MS-12 and his mother were swimming near the shore, we went to the water's edge to photograph the two. With head held high and mouth open in threat display, the mother charged to the beach, left the water, and pursued us up the beach for a distance of 20 feet (Fig. 12). She quickly returned to the water, but repeated the performance when we again went to the water's edge. Re-entering the water, she was about 50 yards from shore and did not see us as we approached the water's edge a third time. Therefore, we yelled loudly at her and once again she charged to shore as before. We found that this behavior was quite dependable and facilitated the capture of her pup for weighing, since the pup always followed close to its mother. The same behavior was noted among mother seals at Kure, with the exception of one female which bellowed and opened her mouth in threat display at a distance of about 50 yards offshore, but refused to charge onto the beach.

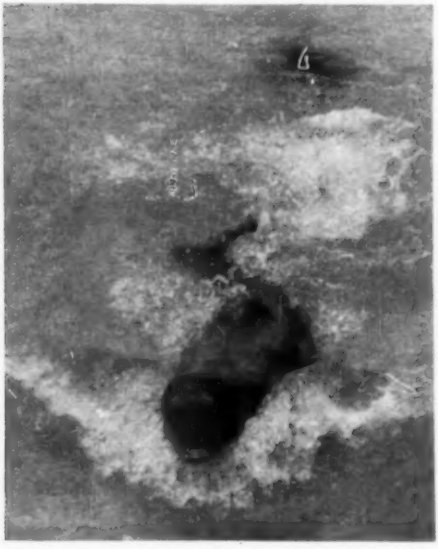

FIG. 12*a*. A mother monk seal, her pup dimly visible beneath the surface behind her, displays threat behavior when charging human observers on the beach. Midway Atoll, May 4, 1957 (KWK 57-17-29).

One exceptionally aggressive mother began a charge on the beach while her newly born pup was in front of her. If we had not changed the direction of her charge by moving to one side, she would have crushed her pup. Although she crushed it only slightly under her chest, it appeared for a few moments to be dazed by having its breath expelled under her weight.

At Pearl and Hermes Reef in late May, 1956, "Tom Frazier, a fisherman, was attacked by an adult seal while spear fishing in about six feet of water near a beach where several new pups and adults were observed. The seal swam rapidly and directly at Frazier with its mouth open and turned away only after being poked repeatedly with a fish spear." (E. C. Jones, FWS, *in lit.*)

The mother of MS-13 would charge at us anywhere along a nearly half-mile stretch of beach, at a considerable distance from the place her pup was born. The display of hostility should probably be interpreted as behavior in defense of her pup rather than defense of a territory.

PHYSICAL CHARACTERS AND GROWTH

Dentition

The tiny milk teeth are apparently resorbed before birth, as in other phocids. When the skull of a 9-pound prematurely born pup (BDM 491) was cleaned, only one of these small teeth could be found.

At birth, the gums of the monk seal pup are almost smooth. Slight irregularities on the surface indicate the position of unerupted teeth, especially the postcanines. At age 27

FIG. 12*b*. Charging from the water and accompanied closely by her pup, a mother monk seal leaves the water to threaten the photographer. Midway Atoll, May 4, 1957 (KWK 57-17-25).

days all permanent lower teeth were erupted. In the upper jaw, the canines and incisors had erupted but only the posterior (fifth) postcanines showed. By the age of 46 days, all teeth were approximately 3 to 5 mm. above the gums.

The adult dentition is (I 2/2, C 1/1, PC 5/5) × 2 = 32.

Pelage and Molt

NATAL PELAGE: On February 27, an aborted 9-pound fetus was found. It was covered with soft black hair, 3 to 6 mm. long, which was slightly and variably curled, giving the surface an irregular ridged appearance. The first three digits of the right front flipper were tipped with white, and there was a small white patch on the belly.

At birth the pup is covered with soft coal-black hair 4 to 8 mm. long, appearing almost velvety, except that the direction of growth can be felt by rubbing with the hand. Rarely a flipper is white tipped at birth but this feature disappears with the first molt.

POSTNATAL MOLT: Four male pups (MS-9, 10, 12, and 13) were observed at frequent but irregular intervals of several days or weeks from birth to the age of more than 2 months.

The rate of molt varied somewhat among individuals. The size of the mother, at the time the pup is born, influences the growth of the pup, and thus indirectly the rate of molt. The pup of a female of maximum size reached a large size before weaning and completed its molt more quickly than a pup that was weaned earlier and at a smaller size by a thinner mother.

The natal hairs fall out individually, not attached to pieces of cuticle as in older animals. The new hair grows in first on the face, chest, neck, and sides. The last areas to lose the natal coat on several pups were the lower back, sides of the abdomen, mid-ventral posterior, abdominal area, and hind flippers.

At age 20 days, a whitish tinge is evident on the muzzle. Light hairs, hidden beneath the black coat, protrude above the surface of the skin, particularly on the neck and chest. At this stage, the black body hair may be pulled out without difficulty. At age 30 days, the black hair is falling rapidly. When we handled the pups, our hands became coated with hair.

The black coat begins to appear "moth-eaten" and has faded from jet black to a dark chocolate brown. At age 39 days, MS-9 had patches of faded natal hair clinging to the lower back, sides, and abdomen, nearly meeting along the mid-ventral line, between the anal and penile openings. At this time, MS-10, the same age as MS-9 but larger, had completed its molt.

By the time the black pup coat is entirely lost, the first postnatal pelage has completely grown in.

ADULT AND SUBADULT PELAGE: After the postnatal molt, the ventral areas are silvery white, darkening to light silvery gray on the sides and dorsally to dark slate gray faintly tinged with a silvery sheen. When wet, the back appears dark sooty brown (Fig. 13).

When the new pelage is fresh, immediately after molting, no yellowish tinge is evident. However, after about a month the light belly may, for unknown reasons, take on a slight yellowish tinge. Before the end of its first year, the pup becomes quite yellowish.

Yearlings and 2-year-olds of both sexes are lighter than older animals.

The color of all adult monk seals observed in fresh pelage was unmarked silvery white or light silvery gray ventrally and dark silvery tinged brown or slate gray dorsally. As the hair ages, the silvery tinge is lost, the ventral surface takes on a decidedly yellowish color and dorsally the hair becomes dull brown, darker in some individuals than in others.

FIG. 13. Male monk seal pup aged 39 days and recently weaned. The black natal coat has been completely lost. The pelage is marked by water splashes. Note extreme obesity. Midway Atoll, May 2, 1957 (KWK 57-17-17).

This is the usual pelage color of winter and early spring.

Adult males are generally darker than females. Some appear almost blackish on their backs and sides. However, a very large dark female was seen, and a nearly adult male was as light as any female seen.

The length of hair on an adult male (BDM 490) ranged from 2 mm. on the flippers to 9 mm. on the belly. The individual hairs are quite stiff and when dry stand fairly erect.

ADULT MOLT: In the subtropical climate of the Leeward Chain, the air temperatures are mild and comparatively uniform (see climate) and seasonally the hours of daylight vary less than at higher latitudes. As might be expected under such conditions, the molting of various individuals is spread over a long period.

The first molting adult, a large female, was seen on May 13. Her molt was complete except for a few irregular ragged patches of loose skin and hair on the lower back. A subadult male, partially molted, was seen on May 23. Among a group of 66 seals seen on June 5, 8 adults and 2 subadults were in the process of molting. Thirteen adults were closely observed on the same day. Of these, 2 had completed their molt and 3 had not begun to molt. Among 8 subadults, 7 had not yet molted and in 1 the molt was one-third complete. Molting subadults were observed on July 29, August 15, and November 18, 1957; molting adults as late as September 10 and 20, and October 1 and 11.

In general, adults appear to molt earlier than subadults. However, no adult females, either in fresh pelage or in the process of molt, were seen with nursing pups. Because of the extent of the pupping season, it is probable that some adult females do not begin their molt until midsummer or later.

A subadult male captured in October, 1955, and held in the Waikiki Aquarium molted in the fall of 1955 and again in April of 1957, and a female in October of 1957 (S. W. Tinker and K. A. Wong, *in lit.*).

The molt begins around the face and neck, proceeding posteriorly along the belly and sides, so that the central dorsal region and hind flippers are last to molt.

Molts subsequent to the first postnatal molt, except for their progression from anterior to posterior and from ventral to dorsal, are quite different from the first molt. The process of molting for the elephant seal is described by Laws (1956). It is said to be "unique, not only among the pinnipeds but among the mammals," and has been called "reptile-like." We were, therefore, interested to observe that Laws' description of the molt in the elephant seal applies remarkably well to that of the adult and subadult Hawaiian monk seal.

When the faded brown and straw-colored hair sloughs off during the spring and summer, it comes off in sheets and patches (Fig. 14) still imbedded in the outer layer of the epidermis (Fig. 15). One patch of shed skin and hair picked up from the beach beside a sleeping adult female, measured roughly 170×100 mm. The hair roots protruded 1 mm. from the lower side, and the old hair 8–10 mm. from the top. When this animal was examined from a distance of about 2 feet, it appeared that where the hair and adhering epidermis had been freshly lost, little or no new hair yet protruded from the blackish, rough skin. However, on the chest and shoulders, the slightly protruding new growth gave the surface a faint silvery sheen.

No animal was seen to roll or scratch to aid the loss of loose patches of skin and hair. Molting seals seemed to behave as usual, both in and out of the water, except for one adult male on October 1 which was reluctant to enter the water and charged the observer with threat display. The captive animal mentioned above fasted during the several weeks of molting. However, the female captured in August, 1955, "ate a fish or two a day but without any spirit" while molting (S. W. Tinker and K. A. Wong, *in lit.*).

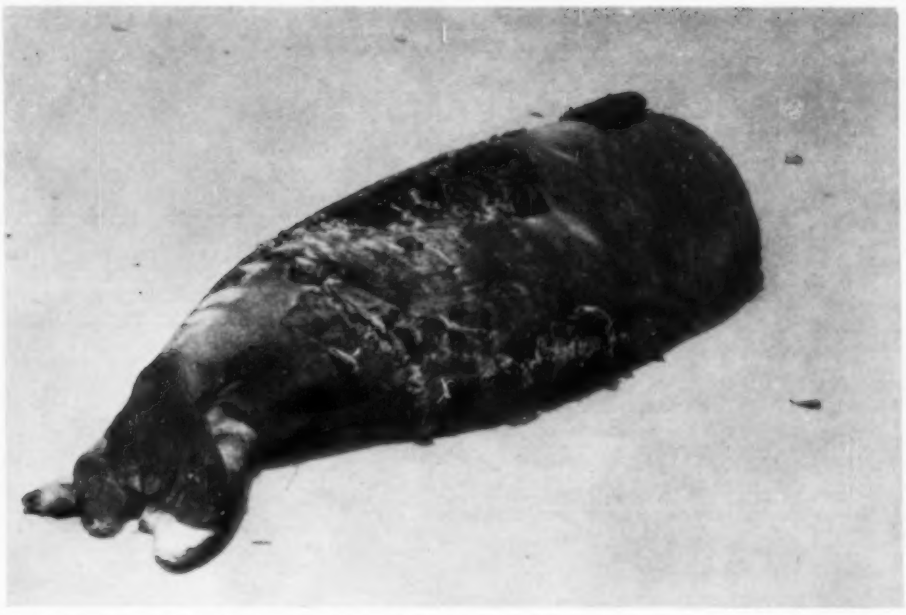

FIG. 14. Molting adult female, ventral view. Sloughing of hair and epidermis during the molt begins around the head and neck, progressing posteriorly and ventrally. The lower back and hind flippers are last to complete the molt. Green Island, Kure Atoll, June 5, 1957 (KWK 57-22-3).

Growth and Body Size

PUPS AND YEARLINGS: Seal pups and yearlings were weighed on 100-pound capacity Chatillon spring scales (Fig. 16). When an animal exceeded the capacity of the scale, two were used in combination. A steel tape was used to measure living pups and yearlings. Because they squirmed energetically, the length measurements (straight line, tip of nose to tip of tail) are not exact. However, the error probably does not exceed ± 1–2 cm. and the mean values are, therefore, useful. Measurements other than standard length were virtually impossible to obtain with our technique from living yearlings.

At birth, the pup weighs about 35 to 38 pounds and its length is roughly 95 to 100 cm. (Table 10). At the age of 17 days, the weight of pup MS-13 had doubled; at age 28 days, its weight had tripled; and when last weighed during the nursing period, at the age of 37 days, its birth weight had nearly quadrupled (Fig. 17). At Midway, the mean weight of three normal pups at the time of weaning was 133 pounds (Fig. 12). At Kure, the largest nursing pup observed had an estimated weight of 150 pounds; the estimated weights of recently weaned pups ranged from 95 to 160 pounds. The length and girth of only one normal pup at the time of weaning was recorded. This pup (MS-13) weighed 142 pounds, its length was 122.5 cm. and its girth was 108.3 cm. Its "degree of fatness" was, therefore, 88.4 (*cf.* Laws, 1953; Sivertsen, 1941; Smirnov, 1924).

After the pup is weaned, it steadily loses weight. Since it has grown relatively little in length during the nursing period, it is exceedingly fat when weaned (Fig. 13) and apparently takes no interest in food. (The apparent increase in weight shown for MS-10

TABLE 10
WEIGHTS AND LENGTHS OF LIVING HAWAIIAN MONK SEALS

DATE, 1957	SEX	AGE	WEIGHT (lbs.)	LENGTH[1] (cm.)
April 2	♂	1 day	36	97.5
April 2	♂	1 day	38	95.0
March 27	♂	4 days	44	102.5
March 27	♂	4 days	46	100.0
Mean for newly born pups			41	98.75
January 14	♂	yearling	112	128.0
March 5	♀	yearling	69	114.0
March 5	♂	yearling	102	129.0
March 5	♀	yearling	92	130.0
March 5	♀	yearling	111	145.0
March 5	♂	yearling	108	136.0
Mean for yearlings			99	130.3

[1] Straight line, tip of nose to tip of tail, animals lying on their bellies.

probably may be attributed to an error in reading the scales.) Considerable observation will be necessary to ascertain when the pup begins to maintain itself by feeding.

The mean weight of six yearlings was 99 pounds, and their mean length 130.3 cm. (Table 10). It is interesting to note that the length of yearlings increases little over that of the newly weaned pup and that newly weaned pups usually weigh considerably more than yearlings. Similar conditions have been shown in other pinnipeds (Scheffer and Wilke, 1953). This indicates that the adjustment from nursing to an independent existence, when the animal must obtain its own food, is strenuous. The substantial store of blubber is undoubtedly a valuable store of nourishment during early attempts to find food.

SUBADULTS AND ADULTS: A young seal, judged to be a yearling, weighed 119 pounds on July 21, 1957, shortly after capture. On September 2, 1957, it weighed 134 pounds and on February 5, 1958, 200 ± 25 pounds, estimated (G. H. Pournelle, *in lit.*). If a curve is projected on the basis of these weights, it appears possible that the monk seal may approach adult size in its third year. A rapid growth rate might be expected, since related forms, the Weddell and crabeater seals, are believed to attain adult size in 1 year (Bertram, 1940).

On February 2, 1957, four adult male monk seals were examined as they lay sleeping on a small islet at Midway. All were about the same size. The one estimated to be slightly largest was shot (now BDM 490). It was cut up and weighed in sections on a 100-pound capacity spring scale. Measurements and weights are recorded below.

Measurements:	
Total length[1]	2,142 mm. (7 ft. ¼ in.)
Front flippers[2]	369 mm.
Hind flippers[2]	342 mm.
Tail	170 mm. (approx.)
Rectum to penile opening	380 mm.
Girth behind flippers	1,300 mm.
Large intestine, length	1,410 mm.
Small intestine, length	2,200 cm. (64 ft. 8 in.)
Thickness of blubber, mid-belly region:	
outer layer	27–29 mm.
inner layer	15–16 mm.
Total	42–45 mm.
Weights (pounds):	
Stomach and contents	8.5
Liver and gall bladder	11.5
Intestines	19.5
Kidneys	2.5
Heart	1.6
Remainder of carcass	336.4
Total	380.0

[1] Tip of nose to tip of tail, animal lying on its back.
[2] Flippers held at right angle to body, measured along anterior margin.

No adult females were collected. The length of a large living female measured as it lay flat on its belly on a smooth sand beach, was 7 feet 8 inches; her weight was estimated at 600 pounds. Fully adult females, in general, appeared larger than males. Pregnant and newly postpartum females are far more obese than any male seen. One large female was estimated to weigh about 575 pounds immediately after the birth of her pup. This

FIG. 15. Cross section of molted hair and epidermis from an adult monk seal. The old faded hair protrudes 8–10 mm. above and the roots 2 mm. below the thin epidermal tissue. Kure Atoll, June 5, 1957 (KWK 57-20-8).

estimate was first made visually. At the end of the nursing period, it was estimated that the mother's weight approximated that of the weighed adult male (380 pounds). Since her pup gained approximately 100 pounds during the 37-day nursing period and it is presumed that the mother lost about 2 pounds for every 1 gained by her pup (*cf.* Laws, 1953), we considered the original estimate quite valid.

ASSOCIATIONS WITH OTHER ORGANISMS

Parasites

Samples of all parasites found in an adult male monk seal, killed on February 2, 1957, at Midway Atoll, were preserved and distributed through Dr. R. A. Rausch to two other specialists. In the future, certain of their findings may be published. A general synopsis of the information now available is presented.

Nematodes, *Contracaecum turgidum:* The esophagus (sample 1, USNM Helm. Coll. 38081) contained a number of minute larvae and a few adults which were much smaller than the approximately 200 individuals which occupied the stomach (sample 2, USNM Helm. Coll. 38080). In addition, a number of individuals were collected from the anterior and posterior portions of the small intestine. Specimens were identified by Mrs. M. B. Chitwood. This species was originally described by Chapin from material collected from the Hawaiian monk seal in 1925. The genus has been recorded from many pinnipeds of the Pacific coast.

Acanthocephalans, *Corynosoma* sp.: Specimens were collected from the anterior portion of the small intestine where they resembled grains of white sand attached to the mucosa. Dr. Yves J. Golvan suspects them of being undescribed. The genus is widely distributed in marine mammals.

Cestodes, *Diphyllobothrium* sp.: The small intestine was heavily infested with cestodes. Our field notes indicate that the smaller worms were found in the anterior part of the small intestine while the larger ones were in

FIG. 16. Weighing male monk seal pup MS-12. Pups and yearlings were weighed on one or a combination of two 100-pound-capacity spring scales. Midway Atoll, May 29, 1957 (KWK 57-18-16).

the posterior. Dr. Rausch informs us that he has separated the specimens into three forms as yet unidentified.

Algae

Almost all seals observed in the field have areas of their pelage tinged greenish by a growth of minute green algae, *Pringsheimiella scutata* (Reinke) Schmidt and Petrack (Fig. 17). According to Yale Dawson, who identified it, this algae is a widespread species epiphytic on various slender green algae. The size and shape of the seal hair seem to be ideal for the growth of this plant. This is apparently the first time it has been found growing on the hair of mammals. On the seals it grows most abundantly around the eyes, nostrils, and lips, in the axillae of the fore and hind flippers, between the digits, and along the side of the body. These are the parts of the pelage least subject to drying when the animals are on land, and for that reason are presumably most favorable for the growth of the algae. Animals remaining several days on land lost the greenish tinge. One very noticeable fact is that the yearling seals have a much more abundant growth of algae than do the adults. *Pringsheimiella* differs greatly from the strands of *Enteromorpha* reported from the grey seal, *Halichoerus grypus* (Mackenzie, 1954), and the harbor seal, *Phoca vitulina* (Scheffer and Slipp, 1944), and from *Ectocarpus* found on fur seals.

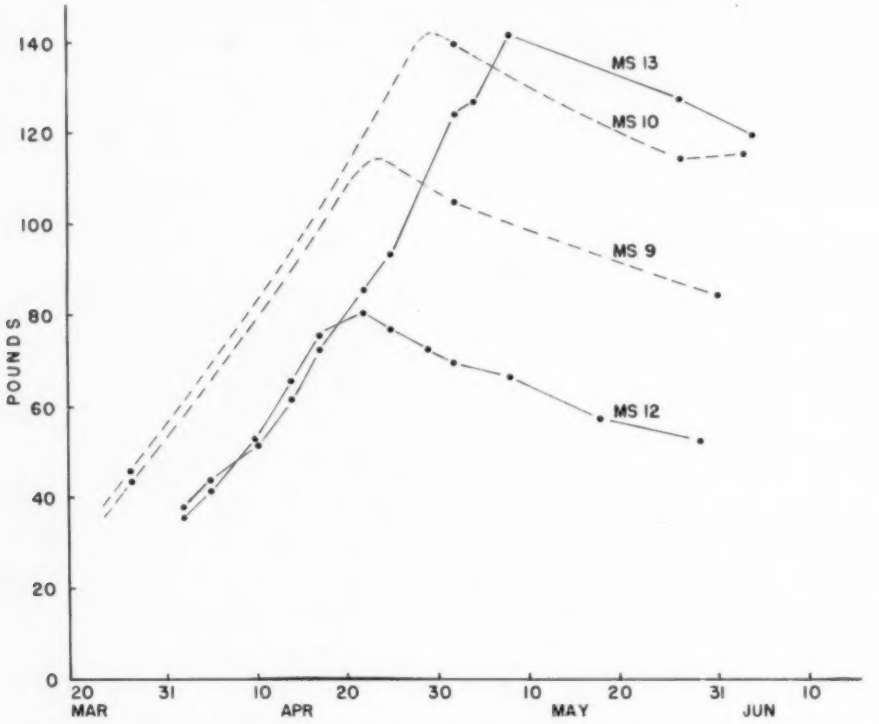

FIG. 17. Growth curves of four male Hawaiian monk seal pups from birth to several weeks after weaning. Dots indicate actual weights. Variation in the length of the nursing period appeared dependent on the obesity of the mother at parturition, the most obese mothers nursing their pups for the longest period.

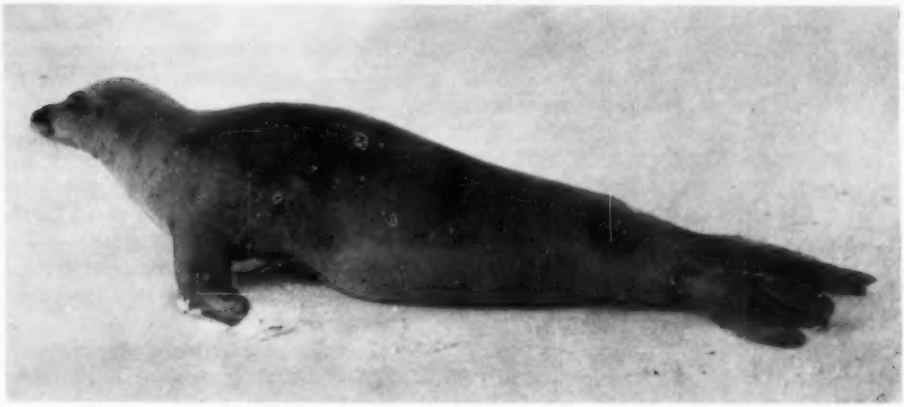

FIG. 18. Subadult monk seal. Dark patches above eye and on muzzle indicate green algae (*Pringsheimiella*) growth. The characteristic mode of progression on land is demonstrated. Midway Atoll, February 2, 1957 (KWK 57-3-5).

Flies

Flies frequently cause seals considerable annoyance. They often cluster about the eyes of sleeping seals. On one occasion, a large female was resting under the *Scaevola* along the upper beach line. Swarms of flies clustered on one of her eyes; at intervals of several seconds, she brushed them away with her foreflipper. After this occurred several times, she crawled onto the open sand where the breeze was strong enough to keep the flies away. Flies swarmed around two open, festering wounds on the back of an old female hauled out on the beach.

On May 4, 1957, we collected several flies found swarming on a healthy subadult seal on Eastern Island. These were identified by Charles R. Joyce, as follows: *Lucilia graphita* Shannon, *Chrysomyia megacephala* Fab., *Phoenicia sericata* (Meigen).

Birds

The islets and beaches where seals haul out are the nesting grounds of thousands of black-footed albatrosses (*Diomedea nigripes*) and Laysan albatrosses (*Diomedea immutabilis*). Thus, the birds are frequently in the proximity of seals. We watched an adult Laysan albatross gaze curiously at a sleeping seal. After slowly walking around the animal, it paused near its head, then reached out and gingerly pecked the seal on the nose. Lurching violently, the seal awoke and the startled albatross took flight. A basking seal threatened a curious black-footed albatross with open jaws. An adult seal threatened an albatross chick which happened to be in its line of travel toward the sea. The chick returned the threats with an aggressive display of beak snapping. When only inches separated the two, the seal altered its course, avoiding the chick which it surely would otherwise have crushed.

On January 31, 1957, we observed a seal, presumably feeding in shallow water north of Eastern Island. Two great frigate birds (*Fregata minor*) were flying about 50 feet above it. Several times the birds dropped down to snatch bits of refuse from the surface—possibly the intestines of fish (the Mediterranean monk seal is said to remove the intestines by squeezing before swallowing the rest of the fish).

SUMMARY

1. The Hawaiian monk seal (*Monachus*

schauinslandi) is similar to the Weddell seal (*Leptonychotes weddelli*) in several aspects of behavior. The molt is epidermal, similar to that of elephant seals (*Mirounga*). Monk seals more nearly resemble the Lobodontinae and Cystophorinae than the Phocinae. It is suggested that the Hawaiian monk seal may be only racially distinct from the Caribbean monk seal (*M. tropicalis*).

2. The Hawaiian monk seal breeds only in the Leeward Chain of the Hawaiian Islands, on Kure Atoll, Midway Atoll, Pearl and Hermes Reef, Lisianski Island, Laysan Island, and French Frigate Shoals. They have occasionally been reported from Maro Reef and Nihoa Island. In the main Hawaiian Islands, they are rarely seen. Sightings are recorded from Hawaii, Oahu, Kauai, and Lehua.

3. Monk seals appear to have few obvious adaptations to their tropical or subtropical environment. Like phocids of cooler regions, they are covered by a thick layer of blubber. A body temperature (35.5°C.), lower than temperatures recorded from seals inhabiting cooler climates, the black skin and black pelage of the pup may have significance in this respect.

4. Habitat requirements include shallow waters (usually near coral reefs) for feeding, sandspits and beaches for hauling grounds, and permanent islets or beaches above high tide for pupping areas.

5. Hawaiian monk seals were nearly exterminated during the nineteenth century, but have now successfully repopulated their former range. Aerial censuses and ground counts in 1956–57 placed the minimum population at 1,013 in the summer of 1957. This included 94 pups, but the count of pups was incomplete at some atolls. Other uncounted seals were undoubtedly at sea.

6. Sex was ascertained in a sample of 154 animals including all age groups. Of these animals, 75 were males and 79 females.

7. The annual reproductive rate (births per 100 animals older than pups) is rather low: about 22 per cent at uninhabited Kure Atoll, and 8 per cent at Midway Atoll where the seals are subject to human disturbance. Field observations suggest that many adult females miss pregnancy each year.

8. Natural mortality among monk seals, both juvenile and adult, appears to be low. At Midway Atoll, six yearling seals were tagged and five pups were born in 1957, suggesting a high survival rate during the first year. A few monk seals carried large scars on their bodies; one apparently died of wounds inflicted by sharks.

9. At Midway Atoll, results of tagging indicate that all of the seals range widely in the lagoon, and share a common home range. Seasonally, seals are most numerous on land during winter months. Daily, they are most numerous on land during the afternoon.

10. While swimming, monk seals regularly use their front flippers, although their hind flippers and fishlike undulation of the body provide the chief means of propulsion.

11. Two distinct vocal sounds are uttered: a deep-throated, soft, bubbling sound (often with mouth closed), and various bellowing sounds.

12. Monk seals are genetically tame, but display threat behavior when closely approached or annoyed, both on land and in the water.

13. No marked social organization was observed. The seals are apparently sexually promiscuous. Courtship behavior was observed from early March to early July.

14. The most important food items in the contents of two seal stomachs were conger eels (*Ariosoma*) and moray eels (*Echidna* and *Gymnothorax*); other items included flatfish (*Bothus*) and cephalopods (octopi?). Apparently the monk seal is primarily a nocturnal bottom feeder, at least while frequenting atolls.

15. The single young is born sometime between late December or January and late June or early July, the majority during April and May. When newly born pups were observed, birth had taken place at night or early morn-

ing. In three cases the fetal membranes had been detached within a few hours after birth.

16. The mother nurses the pup from four abdominal nipples and apparently fasts during the entire nursing period. Weaning normally takes place when the pup is about 5 weeks old, at which time the mother deserts it.

17. The pup can swim at birth but may not normally take to water until the fourth day, after which it spends considerable time in the shallows daily.

18. When moving on land, or when out of sight of each other, mother and pup keep in contact vocally. The mother apparently recognizes her pup by smell. The pup follows its mother closely when she moves about on land and in the water.

19. The mother is affectionate towards her pup, and defends it aggressively from humans and from other seals (except other nursing females).

20. The milk teeth are resorbed before birth. The gums are smooth and toothless at birth. At 27 days after birth, all lower teeth and upper incisors, canines and posterior postcanines were erupted. At 46 days, all teeth were above the gums.

21. During the postnatal molt, the hairs are shed individually. This occurs from about age 20 to 40 days, varying with individuals.

22. The adult molt is epidermal, the outer layer of the epidermis sloughing off in large patches. This occurs between May and November, with the majority of animals molting in June. Parous females do not molt until after the pup is weaned.

23. At birth, pups weigh 35 to 38 pounds. In 5 weeks, they nearly quadruple their weight (average: 133 pounds). After weaning, weight decreases. The average weight of six yearlings was 99 pounds.

24. The growth of a young captive was rapid, indicating that adult size may be approached in the third year. A typical adult male, 7 feet long, weighed 380 pounds. Females average larger; a living 7-foot 8-inch female's weight was estimated at 600 pounds; this animal was one of the largest we observed.

25. An adult male monk seal was heavily parasitized by *Contracaecum turgidum* and three species of *Diphyllobothrium*. An unknown species of *Corynosoma* was less abundant.

26. The pelage of many seals contains a growth of minute green algae, *Pringsheimiella scutata*. Several species of flies (*Lucilia graphita*, *Chrysomyia megacephala*, and *Phoenicia sericata*) cause seals considerable annoyance. There is negligible interspecific friction between albatrosses (*Diomedea nigripes* and *D. immutabilis*) and seals. Frigate birds (*Fregata minor*) were observed following feeding seals to gather scraps.

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Marine Mollusca of the New Hebrides

ALAN SOLEM[1]

THIS PAPER presents a check list of the marine mollusks known from the New Hebrides Islands. In recent years there has been a revival of interest in Indo-Pacific marine shells and active research on their systematics and distribution is being carried on at several centers. Monographic treatments of families and genera are urgently needed, since the taxonomy of most groups is in chaotic condition. Until such monographic treatments become available, critical faunistic studies will be impossible.

Distribution records from faunal reports can be useful to monographers if the authority for identification is cited (see Solem, 1954, for use of such data). In a previous paper on the Solomon Islands fauna (Solem, 1953), no authorities were cited for the identifications. This omission seriously impaired the usefulness of that study and in the present paper is corrected in part. Both studies were carried out at the Chicago Natural History Museum while I was a graduate student at the University of Michigan. Since the summer of 1952 (when my paper of 1953 was submitted for publication) many nomenclatural changes have been recorded in the papers of Kuroda and Habe (1952), Kira (1955), and Demond (1957). These changes are incorporated below, although most of the identifications were completed in 1955. Preparation of the manuscript for publication has been delayed by a detailed study on the New Hebridean land mollusks (Solem, 1959).

MATERIAL STUDIED

The collection initiating this project was made by Robert E. Kuntz on the southeast coast of Espiritu Santo Island from October 1943 to January 1945. His 331 lots of marine shells represented 160 species and morphotypes. All NH and ML numbers refer to Kuntz collecting stations. Information about each site is found in Solem (1959: pl. 2, and Appendix I). About one half of the forms had not been previously reported from the New Hebrides. The Kuntz material is deposited in the University of Michigan Museum of Zoology with a set of duplicates in the Chicago Natural History Museum.

Some miscellaneous lots of New Hebridean marine shells were discovered in various museums and the records are incorporated below. Material from Tangoa Island off Espiritu Santo (Museum of Comparative Zoology), Futuna Island (American Museum of Natural History), Rano Island off northeast Malekula (Chicago Natural History Museum), and Cape Lisburn, Espiritu Santo (gift of Harold Harry to Chicago Natural History Museum) was examined.

PREVIOUS STUDIES

Surprisingly little has been published on the New Hebridean marine fauna. Both Bougainville and Cook visited the islands in the late 1700's, but no New Hebridean mollusks are known to have been brought back from their voyages (von Martens, 1872*a*, 1872*b*). On August 24, 1829, George Bennett collected a living *Nautilus pompilius* at Dillon's Bay, Erromanga (Owen, 1832), and about the same time the "Astrolabe" scientists found 62 species of marine shells at Ticopia and Vanikoro in the neighboring Santa Cruz Islands (Quoy and Gaimard, 1832–1835). Dohrn (1864), H. Adams (1872), Baird (in Brenchley, 1873), Brazier (1894, 1896), Dautzenberg (1900), Fischer (1902), and Willey (1902) published brief notes or descriptions.

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Mabille (1895) studied a small collection, Hedley (1899) included New Hebridean distribution records in his Funafuti report, C. R. Boettger (1916) listed a few marine shells, and Ingram and Kenyon (1946) recorded cowries from Espiritu Santo.

The only comprehensive studies are those of Fischer and Fischer-Piette (1938, 1939) on recent marine shells and of Abrard (1946) on fossils. Two short lists appearing in the *Minutes of the Conchological Club of Southern California*, no. 23 (1943) are ignored, since the identifications of one collection were found to be unreliable.

SYSTEMATIC LIST

The classification is slightly modified from Thiele (1929–1935). Specific and generic nomenclature follows recent Japanese useage, with the often more familiar synonyms usually being cited. Trinomials, when used, represent marked morphologic variants whose taxonomic status is uncertain. They do not represent "subspecies."

Identifications have been made from the Chicago Natural History Museum collection and have been checked against original illustrations whenever possible. For convenience, however, I have cited a reference figure from an easily available source, such as Hirase and Taki (1951) or Kira (1955), for many of the common species. Other reference figures are from the standard iconographies of Kiener, Reeve, Sowerby, Martini and Chemnitz (2nd edition), and the *Manual of Conchology*. A similar procedure was adopted by Demond (1957).

The following symbols indicate the sources of the species listed:

AMNH	American Museum of Natural History
Boettger	C. R. Boettger (1916)
Brazier	Brazier (1894, 1896)
CNHM	Chicago Natural History Museum
F	Fischer and Fischer-Piette (1938, 1939)
H	Donated by Harold Harry
Hedley	Hedley (1899)
IK	Ingram and Kenyon (1946)
Mabille	Mabille (1895)
MCZ	Museum of Comparative Zoology
ML	Collecting station on Espiritu Santo
NH	Same as ML
S	Schilder and Schilder (1952)

Class *PELECYPODA*

Family ARCIDAE

Anadara pilula Reeve **F**

Anadara rhombea Born **F**

Anadara scapha Meuschen Kira (1955: pl. 43, fig. 12); **NH** 8

Arca imbricata imbricata Gmelin **F**

Arca imbricata avellana Lamarck (=*maculata* Sowerby) Reeve, *Arca*, pl. XI, fig. 71; **NH** 14, New Hebrides (**Hedley**)

Barbatia bicolorata Dillwyn (=*fusca* Bruguière, *non* Solander) **F**

Barbatia lima Reeve (=*decussata* of authors, *non* Sowerby) Kira (1955: pl. 42, fig. 12); Tangoa, Espiritu Santo

Barbatia ovata Gmelin (=*nivea* Chemnitz) Reeve, *Arca*, pl. XIV, fig. 90; **NH** 4, **NH** 5, **NH** 9, New Hebrides (**F**)

Family GLYCYMERIDAE

Glycymeris (*Veletuceta*) *reevei* Mayer **F**

Family NUCULIDAE

Leda verconis Tate Roy. Soc. So. Austral., Trans. 1891: 261, pl. 11, fig. 4 **F**

Family MYTILIDAE

Brachidontes (*Septifer*) *bilocularis* Linné Hirase and Taki (1951: pl. 18, fig. 2); **NH** 7, **F**

Brachidontes (*Brachidontes*) *crebristriatus* Conrad Dall, Bartsch, and Rehder (1938: pl. 8, figs. 5–8); **ML** 28

Modiolus auriculatus Krauss (=*moduloides* Röding?) **F**

Family VULSELLIDAE

Isognomon isognomum Linné **F**
Isognomon nucleus Lamarck **F**
Isognomon quadrangularis Reeve Immer (**Boettger**)
Isognomon sulcatum Lamarck Reeve, *Perna*, pl. 4, fig. 6; **NH** 9, **NH** 12, **NH** 14, **F**
Isognomon vitreum Reeve **F**

Family PINNIDAE

Pinna rumphii Hanley **F**

Family PECTENIDAE

Aequipecten pallium Linné **F**, Erromanga (**Hedley**)
Chlamys squamatus Gmelin **F**
Comptopallium radula Linné **F**
Cryptopecten inaequivalvis Sowerby **F**
Plicatula plicatus Linné Reeve, *Plicatula*, pl. II, fig. 5; **NH** 13, **F**
Spondylus ducalis Röding **F**
Spondylus linguafelis Sowerby **F**
Spondylus nicobaricus zonalis Lamarck **F**
Spondylus variegatus "Chemnitz" **F**

Family LIMIDAE

Lima alata Hedley **F**
Lima annulata Lamarck **F**

Family OSTREIDAE

Ostraea cristagalli Linné Reeve, *Ostraea*, pl. XXVIII, fig. 72; Havannah Harbour, Vate (**Hedley**)
Ostraea forskali Gmelin **F**
Ostraea paulucciae Crosse (=*palmipes* Sowerby) **F**
Ostraea plicatula Gmelin **F**

Family CORBICULIDAE

Polymesoda (*Geloina*) *cyprinoides* Quoy and Gaimard Martini and Chemnitz, IX(3): pl. 20, figs. 3, 4; **ML** 75
Polymesoda (*Geloina*) *ingens* Dautzenberg (= *cyprinoides* Quoy & Gaimard?) Dautzenberg (1900: pl. 5); Espiritu Santo (Dautzenberg, 1900)

Family CARDITIDAE

Beguina (*Mytilicardita*) *aviculina* Lamarck Reeve, *Cardita*, pl. IV, fig. 18; **NH** 9
Beguina (*Mytilicardita*) *variegata* Bruguière **F**
Venericardia ovalis Reeve **F**

Family LUCINIDAE

Codakia (*Codakia*) *tigerina* Linné **F**
Codakia (*Jagonia*) *divergens* Philippi New Hebrides (**Hedley**), **F**
Fimbria fimbriata Linné **F**
Loripes assimilis Angas **F**
Lucina (*Lucina*) *edentula* Linné **F**

Family CHAMIDAE

Chama asperella Lamarck **F**
Chama imbricata Broderip Zool. Soc. London, Trans. 1835: pl. 39, fig. 1; Aneiteum (**Hedley**)

Family CARDIIDAE

Fragum fragum Linné **F**
Fragum nivale Reeve **F**
Papyridea (*Fulvia*) *australis* Sowerby **F**
Trachycardium flavum dupuchense Reeve **F**

Family TRIDACNIDAE

Hippopus hippopus Linné Kira (1955: pl. 55, fig. 15); Tangoa, Espiritu Santo (**MCZ**)

Family VENERIDAE

Circe (*Circe*) *plana* Odhner K. vetensk. Akad. Handl., 52(16): pl. 1, figs. 23–25; **NH** 5
Dosinia aff. *angulosa* Philippi **F**
Gafrarium dispar mixtum Lamarck **F**
Gafrarium pectinatum Lamarck **F**
Gafrarium tumidum Röding (=*gibbium* Lamarck) Hirase and Taki (1951: pl. 33, fig. 3); **NH** 5, **NH** 9
Lioconcha castrensis Linné Kira (1955: pl. 57, fig. 3); **ML** 28, Aneiteum (**Hedley**), **F**
Lioconcha ornata Dillwyn (=*picta* Lamarck) **F**
Pitar (*Lepidocardia*) *australica* Reeve **F**
Pitar (*Pitarina*) *citrina* Lamarck **F**
Pitar (*Paradione*) *erycina* Linné **F**
Pitar (*Lepidocardia*) *florida* Lamarck **F**

Pitar (*Paradione*) *philippinarum* Hanley **F**
Tapes litteratus Linné **F**
Venerupis (*Amygdala*) *variegata* Sowerby Hirase and Taki (1951: pl. 40, fig. 6); **NH** 7, **F**
Venus (*Periglypta*) *lacerata* Hanley **F**
Venus (*Leucoma*) *marica* Linné **F**
Venus (*Periglypta*) *puerpera* Linné Hirase and Taki (1951: pl. 36, fig. 2); **NH** 9
Venus (*Periglypta*) *reticulata* Linné **F**

Family MESODESMATIDAE

Mesodesma (*Atactodea*) *glabratum* Gmelin **F**
Mesodesma (*Davila*) *planum* Hanley **F**
Mesodesma (*Atactodea*) *striatum* Lamarck Reeve, *Mesodesma*, pl. 2, fig. 10; **NH** 5, **NH** 9
Mesodesma (*Atactodea*) *trigona* Deshayes Reeve, *Mesodesma*, pl. III, fig. 19; Tangoa, Espiritu Santo (**MCZ**)

Family MACTRIDAE

Cardilia semisulcata Lamarck **F**
Mactra (*Mactra*) *cuneata* Gmelin **F**
Mactra (*Mactra*) *kanakina* Souverbie **F**
Mactra (*Mactra*) *maculata* Gmelin **F**

Family DONACIDAE

Donax crenatus Linné **F**
Donax tinctus Gould **F**

Family GARIDAE

Asaphis (*Asaphis*) *deflorata* Linné Vate (**Hedley**), Immer (**Boettger**), **F**
Sanguinolaria (*Soletellina*) *elongata* Lamarck (= *violacea* Lamarck) **F**

Family TELLINIDAE

Angulus (*Tellinides*) *apalinus* Gmelin **F**
Angulus (*Exotica*) *clathrata* Deshayes (= *rhomboides* Quoy & Gaimard) **F**
Angulus (*Angulus*) *rubellus* Deshayes **F**
Arcopagia (*Arcopaginula*) *inflata* Gmelin **F**
Arcopagia (*Pinguitellina*) *robusta* Hanley **F**
Arcopagia (*Arcopagia*) *subelliptica* Sowerby **F**
Cyclotellina (*Cyclotellina*) *remies* Linné **F**
Cyclotellina (*Scutarcopagia*) *scobinata* Linné Hirase and Taki (1951: pl. 44, fig. 1); **NH** 9, **F**
Quadrans (*Quidnipagus*) *palatam* Iredale (= *rugosa* Born) **F**
Strigilla (*Strigilla*) *splendida* Anton **F**
Tellina (*Tellina*) *crucigera* Lamarck **F**
Tellina (*Pharaonella*) *perna* Spengler **F**
Tellina (*Tellinella*) *petalina* Deshayes **F**
Tellina (*Tellina*) *virgata* Linné (= *jubar* Hanley) **F**

Family PHOLADIDAE

Jouannetia (*Triomphalia*) *globulosa* Quoy and Gaimard **F**

Family TEREDINIDAE

Bankia bipalmulata Lamarck Turtle Bay, Espiritu Santo (**MCZ**)

Class *CEPHALOPODA*

Family NAUTILIDAE

Nautilus pompilius Linné Tangoa, Espiritu Santo (**MCZ**), Dillon's Bay, Erromanga and Aneiteum (Bennett, 1860)

Class *GASTROPODA*
Subclass *OPISTHOBRANCHIA*

Family ACTAEONIDAE

Pupa sulcata Gmelin Man. Conch. (1)15: pl. 20A, figs. 39, 46–48; Aneiteum (**Hedley**)

Family BULLIDAE

Bulla (*Bulla*) *adamsi* Menke Man. Conch., (1)15: pl. 35, figs. 15, 16, 19, 20; Malekula (**CNHM**)

Family ATYIDAE

Atys (*Atys*) *naucum* Linné **F**
Haminoea crocata Pease **F**
Smaragdinella (*Smaragdinella*) *viridis* Rang **F**

Family OXYNOIDAE

Oxynoe hargravesi H. Adams H. Adams (1872: pl. 3, fig. 30); New Hebrides (type locality)

Subclass *PULMONATA*

Family SIPHONARIIDAE

Siphonaria laciniosa Linné Hirase and Taki (1951: pl. 121, fig. 11); **NH** 5

Subclass *PROSOBRANCHIA*

Family HALIOTIDAE

Haliotis (*Sanhaliotis*) *dohrniana* Dunker Man. Conch., (1)12: pl. 7, figs. 39–41; New Hebrides (type locality), Tangoa, Espiritu Santo (**MCZ**)

Haliotis (*Haliotis*) *pustulata* Reeve (=*dohrniana* Dunker?) Vate (**F**)

Haliotis (*Haliotis*) *stomatiaeformis* Reeve Tanna (**F**)

Haliotis (*Sanhaliotis*) *varia* Linné Man. Conch., (1)12: pl. 23, figs. 53–55; **NH** 13

Family FISSURELLIDAE

Clypidina lamberti Souverbie Tanna (**F**)

Diodora lineata Sowerby Man. Conch., (1)13: pl. 63, figs. 29, 30; **NH** 1, New Hebrides (**CNHM**)

Emarginula (*Emarginula*) *scabricostata* Adams Nguna (**F**)

Family PATELLIDAE

Patella (*Scutellastra*) *stellaeformis* Reeve Kira (1955: pl. 5, fig. 6); Cape Lisburn, Espiritu Santo (**H**), **F**

Cellana amusitata Reeve **F**

Cellana nigrolineata Reeve Immer (**Boettger**)

Cellana testudinaria Linné Vanua-Lava (**F**), Tanna (**F**)

Family TROCHIDAE

Chrysostoma paradoxum Born Hirase and Taki (1951: pl. 67, fig. 1); **NH** 12, **NH** 13, **NH** 14, Immer (**Boettger**)

Diloma (*Melagraphia*) *constellata* Souverbie Anelgauhaut Harbor, Aneiteum (**Brazier**)

Euchelus (*Euchelus*) *atratus* Gmelin Man. Conch., (1)11: pl. 38, fig. 22; **NH** 4, **NH** 5, **NH** 9, **NH** 11, **NH** 12, **NH** 13, Vate (**F**)

Gena (*Plocamotis*) *lutea* Adams **F**

Monilea (*Talopena*) *lifuana* Fischer Man. Conch., (1)11: pl. 41, figs. 6, 7; Aneiteum (**Hedley**)

Monodonta (*Monodonta*) *canalifera* Lamarck Immer (**Boettger**)

Stomatella (*Stomatella*) *sulcifera* Lamarck Malekula (**F**)

Stomatia (*Stomatia*) *angulata* Adams **F**

Stomatia (*Stomatia*) *phymotis phymotis* Helbing **F**

Stomatia (*Stomatia*) *phymotis australis* Adams Man. Conch., (1)12: pl. 54, figs. 1–3; **NH** 4

Tectus (*Cardinalia*) *fenestratus* Gmelin Kiener, *Trochus*, pl. 38, fig. 3; **NH** 4, **NH** 11, **NH** 13, **NH** 14, Espiritu Santo (**F**)

Tectus (*Rochia*) *niloticus* Linné Hirase and Taki (1951: pl. 65, fig. 6); **NH** 9, **NH** 12, **NH** 13, **NH** 14

Tectus (*Tectus*) *pyramis* Born (=*obeliscus* Gmelin) Hirase and Taki (1951: pl. 65, fig. 8); **NH** 8, Cape Lisburn, Espiritu Santo (**H**)

Tegula (*Chlorostoma*) *pfefferi* Dohrn (=*dohrni* Pilsbry) Man. Conch., (1)11: 189, pl. 61, figs. 28–29; New Hebrides (type locality), Anelgauhaut Harbor, Aneiteum (**Brazier**)

Trochus (*Trochus*) *incrassatus incrassatus* Lamarck **F**

Trochus (*Trochus*) *incrassatus creniferus* Kiener Kiener, *Trochus*, pl. 34, fig. 3; Cape Lisburn, Espiritu Santo (**H**)

Trochus (*Trochus*) *maculatus maculatus* Linné Hanley, Ipsa Conchologia Linnaei, pl. 3, fig. 7; **NH** 12, **NH** 13, Vate (**F**)

Trochus (*Trochus*) *maculatus granosus* Lamarck Kiener, *Trochus*, pl. 34, fig. 1; **ML** 6, **NH** 8, **NH** 9, **NH** 14

Trochus (*Trochus*) *maculatus verrucosus* Gmelin Kiener, *Trochus*, pl. 109, fig. 4; **NH** 5

Trochus (*Infundibulum*) *tubiferus* Kiener **F**

Family ANGARIIDAE

Angaria delphinus delphinus Linné Hirase and Taki (1951: pl. 71, fig. 8); **NH** 7, **NH**

8, **NH** 9, Vate (**F**)
Angaria delphinus atrata Reeve Espiritu Santo (**F**)

Family TURBINIDAE

Astraea (*Calcar*) *stellaris* Gmelin Man. Conch., (1)10: pl. 55, figs. 66–68; **NH** 9, Vate (**F**)
Liotia (*Liotia*) *peronii* Kiener **F**
Liotia (*Arene*) *crenata* Kiener Man. Conch., (1)10: pl. 36, figs. 12, 13; Aneiteum (**Hedley**)
Turbo (*Marmarostoma*) *argyrostomus argyrostomus* Linné Hirase and Taki (1951: pl. 73, fig. 4); **NH** 9
Turbo (*Marmarostoma*) *argyrostomus margaritaceus* Linné Man. Conch., (1)10: pl. 45, fig. 100: **ML** 6, **NH** 8, **NH** 9
Turbo (*Marmarostoma*) *chrysostomus* Linné Man. Conch., (1)10: pl. 40, fig. 19; **NH** 8, **NH** 12, **NH** 13, **NH** 14
Turbo (*Marmarostoma*) *crassus* Wood Man. Conch., (1)10: pl. 47, fig. 20; Tangoa, Espiritu Santo (**MCZ**), Vate (**F**)
Turbo (*Olearia*) *marmoratus* Linné Kira (1955: pl. 9, fig. 7); Tangoa, Espiritu Santo (**MCZ**)
Turbo (*Turbo*) *petholatus* Linné Hirase and Taki (1951: pl. 73, fig. 1); **NH** 8
Turbo (*Lunella*) *porphyrites* Gmelin Man. Conch., (1)10: pl. 50, fig. 58; **NH** 8, **NH** 9
Turbo (*Marmarostoma*) *setosus setosus* Gmelin Espiritu Santo (**F**)
Turbo (*Marmarostoma*) *setosus patulus* Philippi Man. Conch., (1)10: pl. 63, fig. 33; **NH** 8, **NH** 11

Family PHASIANELLIDAE

Phasianella (*Orthomesium*) *variegata* Lamarck Tanna (**F**)
Phasianella (*Orthomesium*) *wisemanni* Baird Brenchley (1873: pl. 38, fig. 34); Aneiteum (type locality), New Hebrides (**CNHM**)

Family NERITIDAE

The genus *Neritina* is not considered at this time, since, like the Thiaridae, it primarily inhabits fresh or brackish waters.

Nerita (*Theliostyla*) *albicilla* Linné Hirase and Taki (1951: pl. 75, fig. 8); **NH** 1, **NH** 4, **NH** 9, **NH** 13, Erromanga (**Hedley**), Tangoa, Espiritu Santo (**MCZ**)
Nerita (*Ritena*) *grossa* Linné Man. Conch., (1)10: pl. 5, fig. 85; **NH** 7, Vate (**F**)
Nerita (*Amphinerita*) *maxima* Gmelin Martini and Chemnitz, II(11): pl. 6, figs. 1–5; Aneiteum (**Hedley**)
Nerita (*Theliostyla*) *patula* Recluz Man. Conch., (1)10: pl. 3, figs. 52, 55; **NH** 8
Nerita (*Ritena*) *plicata* Linné Martini and Chemnitz, II(11): pl. 10, figs. 7, 10; **NH** 5, **NH** 8, **NH** 9, **NH** 11, **NH** 12, **NH** 13, Erromanga (**Hedley**), Immer (**Boettger**), New Hebrides (**F**)
Nerita (*Amphinerita*) *polita* Linné Hirase and Taki (1951: pl. 75, fig. 13); **ML** 42, **NH** 1, **NH** 5, **NH** 7, **NH** 8, **NH** 9, **NH** 13, **NH** 14, Vate (**F**), Espiritu Santo (**F**), Erromanga (**Hedley**), Tangoa, Espiritu Santo (**MCZ**), New Hebrides (**Mabille**)
Nerita (*Nerita*) *signata* Lamarck (= *reticulata* Karsten) Man. Conch., (1)10: pl. 3, fig. 49; **ML** 28, **NH** 7, **NH** 9, **NH** 12, **NH** 13
Nerita (*Ritena*) *undata* Linné Man. Conch., (1)10: pl. 5, fig. 87; **NH** 1, **NH** 5, **NH** 7, **NH** 8, **NH** 9, **NH** 13, **NH** 14, Immer (**Boettger**)

Family LITTORINIDAE

Littorina (*Melaraphe*) *mauritiana* Lamarck Reeve, *Littorina*, pl. XVII, fig. 100; New Hebrides (**Mabille**)
Littorina (*Melaraphe*) *coccinea* Gmelin (= *obesa* Sowerby) Man. Conch., (1)9: pl. 43, fig. 53; Vate (**Hedley**)
Littorinopsis (*Littorinopsis*) *scabra scabra* Linné Hirase and Taki (1951: pl. 79, fig. 13); **ML** 6, **ML** 28, **NH** 11, 4K**ML**, Surenda, Espiritu Santo (**F**), Hog Harbor, Espiritu Santo (**MCZ**), Immer (**Boettger**), Lagune d'Erakor, Vate (**F**)

Littorinopsis (*Littorinopsis*) *scabra filosa* Sowerby Man. Conch., (1)9: pl. 43, figs. 31, 31a; **ML** 6

Littorinopsis (*Littorinopsis*) *scabra intermedia* Philippi Reeve, *Littorina*, pl. VI, fig. 28a; New Hebrides (**Mabille**)

Littorinopsis (*Littorinopsis*) *undulatus* "Martyn" Gray Hirase and Taki (1951: pl. 79, fig. 11); **NH** 7, **NH** 8, **NH** 12

Echininus cumingi Philippi H. and A. Adams, Genera of recent shells, 3: pl. 33, fig. 3; **NH** 8, Vate (**F**), New Hebrides (**Mabille**)

Family RISSOIDAE

Rissoina ambigua Gould Vate (**F**), Tanna (**F**)

Rissoina exasperata Souverbie Vate (**F**)

Rissoina plicata Adams Vate (**F**)

Family SOLARIIDAE

Philippia hybridum Linné Sarakata, Espiritu Santo (**F**)

Philippia radiata Röding (=*cingulum* Kiener) Kiener, *Solarium*, pl. 3, fig. 6; **NH** 12, **NH** 13

Family VERMETIDAE

Vermetus dentifer Lamarck **F**

Family PLANAXIDAE

Planaxis (*Quoyia*) *decollatus* Quoy and Gaimard New Hebrides (**Mabille**)

Planaxis (*Planaxis*) *lineatus* DaCosta Hirase and Taki (1951: pl. 79, fig. 17); New Hebrides (**Hedley**)

Planaxis (*Planaxis*) *nigra* Quoy and Gaimard Reeve, *Planaxis*, pl. II, fig. 13; New Hebrides (**Mabille**)

Planaxis (*Planaxis*) *sulcatus* Born Hirase and Taki (1951: pl. 79, fig. 16); **ML** 6, Immer (**Boettger**)

Family POTAMIDIDAE

Terebralia palustris Bruguière Immer (**Boettger**)

Family CERITHIIDAE

The traditional generic useage is followed here, rather than the newer concepts of Iredale and of most Japanese workers.

Aluco aluco Linné Hirase and Taki (1951: pl. 83, fig. 7); **NH** 1, **NH** 4; adults measure 49–66.4 mm. in length

Cerithium columna Sowerby Hirase and Taki (1951: pl. 83, fig. 9); **NH** 4, **NH** 8, **NH** 9, **NH** 13, **NH** 14, Vate (**F**)

Cerithium echinatum Lamarck Kiener, *Cerithium*, pl. 3, fig. 1; **NH** 9

Cerithium nodulosum Bruguière (=*Contumax decollatus* Hedley) Hirase and Taki (1951: pl. 83, fig. 8); **NH** 14

Cerithium consisum Hombron and Jacquinot (=*morus* Lamarck) Man. Conch., (1)9: pl. 24, figs. 29–33; **NH** 4, **NH** 5, **NH** 8, **NH** 9, **NH** 13

Cerithium consisum sejunctum Iredale (=*variegatum* Quoy and Gaimard) **F**

Cerithium consisum vittatum Sowerby **F**

Ischnocerithium rostratum Sowerby Man. Conch., (1)9: pl. 23, figs. 90, 91; Vate (**F**), New Hebrides (**Hedley**)

Liocerithium piperitum Sowerby Man. Conch., (1)9: pl. 27, fig. 31; **NH** 13, Vate (**F**)

Proclava zebra Kiener Man. Conch., (1)9: pl. 25, figs. 71, 72; New Hebrides (**Hedley**)

Rhinoclavis asperus Linné Hirase and Taki (1951: pl. 83, fig. 1); **NH** 5, **NH** 8

Rhinoclavis fasciatus Bruguière Man. Conch., (1)9: pl. 29, figs. 65–67; Segond Channel, Espiritu Santo (**MCZ**), Espiritu Santo (**F**)

Rhinoclavis pharos Hinds Man. Conch., (1)9: pl. 29, fig. 68; New Hebrides (**Hedley**)

Rhinoclavis sinense Gmelin (=*obeliscus* Bruguière) Hirase and Taki (1951: pl. 83, fig. 4); **NH** 4, **NH** 9, **NH** 13, **F**

Rhinoclavis vertagus Linné Espiritu Santo (**F**), Vate (**F**)

Semivertagus nesioticus Pilsbry and Vanatta (=*lacteus* Kiener and *collacteum* Iredale) Kiener, *Cerithium*, pl. 7, fig. 3; **NH** 12, **NH** 13

Family EPITONIIDAE

Epitonium (*Limiscala*) *lyra* Sowerby Sarakata, Espiritu Santo (**F**)

Cirsotrema (*Coronoscala*) *perplexa* Pease Sarakata, Espiritu Santo (**F**)

Family EULIMIDAE

Eulima hargravesi Brazier (=*porcellana* H. Adams, *preocc.*) Adams (1872: pl. 3, fig. 29); New Hebrides (type locality), Aneiteum (**Brazier**)

Family VANIKORIDAE

Vanikoro cancellata Lamarck Surenda, Espiritu Santo (**F**)

Family AMALTHEIDAE

Amalthea (*Amalthea*) *australis* Quoy and Gaimard (=*conica* Schumacher ?) Man. Conch., (1)8: pl. 41, figs. 12, 13; **NH** 12, **NH** 13, **NH** 14, Tangoa, Espiritu Santo (**MCZ**)

Family CAPULIDAE

Capulus (*Krebsia*) *intortus* Lamarck Man. Conch., (1)8: pl. 39, figs. 75, 76; Aneiteum (**Hedley**)

Capulus (*Capulus*) *violaceus* Angas Man. Conch., (1)8: pl. 39, fig. 81; New Hebrides (**Hedley**)

Family STROMBIDAE

Canarium (*Euprotomus*) *aurisdianae* Linné (=*guttatus* Martini) Kira (1955: pl. 16, fig. 2); Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**)

Canarium (*Labiostrombus*) *canarium* Linné Espiritu Santo (**F**)

Canarium (*Canarium*) *dentatum* Linné Kira (1955: pl. 15, fig. 3—as *tridentatum* Gmelin); **NH** 14

Canarium (*Oostrombus*) *gibberulum* Linné Man. Conch., (1)7: pl. 8, fig. 85; **NH** 1, **NH** 5, **NH** 9, **NH** 12, Vate (**F**), New Hebrides (**Hedley**)

Canarium (*Canarium*) *labiatus* Röding (=*ustulatus plicatus* Lamarck) Dodge (1946: figs. 3, 7; also 1956: 285); **NH** 9

Canarium (*Euprotomus*) *latissimus* Linné Espiritu Santo (**F**)

Canarium (*Euprotomus*) *lentiginosus* Linné Hirase and Taki (1951: pl. 86, fig. 4); **NH** 8, Tangoa, Espiritu Santo (**MCZ**), Espiritu Santo (**F**)

Canarium (*Canarium*) *mutabilis* Swainson (=*floridanum* Lamarck) Dodge (1946: figs. 4, 8); **NH** 4, **NH** 5, **NH** 9, **NH** 11, **NH** 12, **NH** 13, **NH** 14, Espiritu Santo (**F**), Cape Lisburn, Espiritu Santo (**H**), Vate (**F**), Erromanga (**Hedley**), Malekula (**CNHM**)

Canarium (*Labiostrombus*) *variabile* Swainson Man. Conch., (1)7: pl. 6, figs. 59, 60; **NH** 10, Cape Lisburn, Espiritu Santo (**H**)

Lambis truncata Solander (=*bryonia* Gmelin) Erromanga (**Hedley**)

Lambis scorpio Linné Hirase and Taki (1951: pl. 88, fig. 1); Cape Lisburn, Espiritu Santo (**H**)

Terebellum terebellum Linné Hirase and Taki (1951: pl. 89, fig. 1); **NH** 9, Erromanga (**Hedley**)

Family NATICIDAE

Natica (*Natica*) *marochiensis* Gmelin Man. Conch., (1)8: pl. 5, fig. 75; **NH** 7, **NH** 9, **NH** 12, New Hebrides (**Hedley**)

Specimens from NH 7 have the typical color pattern; those from NH 9 and NH 12 have two spiral bands of brown on a yellowish background.

Natica (*Natica*) *solida* Blainville Man. Conch., (1)8: pl. 20, fig. 98; **NH** 12

Natica (*Natica*) *traillii* Reeve **F**

Polinices (*Polinices*) *albumen* Linné Hirase and Taki (1951: pl. 91, fig. 7); **NH** 4 (juvenile), Cape Lisburn, Espiritu Santo (**H**)

Polinices (*Polinices*) *flemingianus* Récluz Hirase and Taki (1951: pl. 91, fig. 5); **NH** 5, **NH** 9, **NH** 12

Polinices (*Mamilla*) *mammilla* Linné (=*pyriformis* Récluz) Kira (1955*c* pl. 17, fig. 10); **NH** 4, **NH** 7, **NH** 10, **NH** 12

Polinices (*Mamilla*) *melanostoma* Gmelin Man. Conch., (1)8: pl. 21, fig. 14; **NH** 7, **NH** 11, Vate (**F**)

NH 11 is var. *melanostomoides* Quoy and

Gaimard which F reported as a distinct species from Vate.

Family OVULIDAE
(=AMPHIPERATIDAE)

Calpurnus verrucosus Linné Hirase and Taki (1951: pl. 94, fig. 20); Futuna (**AMNH**)
Ovula ovum Linné Espiritu Santo (**F**)

Family ERATOIDAE

Trivirostra oryza Lamarck New Hebrides (**Hedley**)

Family CYPRAEIDAE

No attempt has been made to utilize the elaborate subspecific categories proposed by the Schilders and many of their split genera are ignored. No reference figures are quoted.

Callistocypraea (*Chelycypraea*) *testudinaria* Linné Aneiteum (**Hedley**)
Cypraea (*Lyncina*) *carneola* Linné Espiritu Santo (**F, IK**)
Cypraea (*Lyncina*) *lynx* Linné Segond Channel, Espiritu Santo (**MCZ**), Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F, IK**), Erromanga (**Hedley**), Malekula (**CNHM**)
Cypraea (*Cypraea*) *tigris* Linné Espiritu Santo (**F**), Erromanga (**Hedley**)
Cypraea (*Lyncina*) *vitellus* Linné Segond Channel, Espiritu Santo (**MCZ**), Espiritu Santo (**IK**), Vate (**F**)
Erosaria (*Ravitrona*) *caputserpentis* Linné **ML** 6, **NH** 14, Tangoa, Espiritu Santo (**MCZ**), Espiritu Santo (**IK**), Vate (**F**), Erromanga (**Hedley**)
Erosaria (*Erosaria*) *erosa* Linné **NH** 8, Espiritu Santo (**F**), Erromanga (**Hedley**)
Erosaria (*Erosaria*) *helvola* Linné Espiritu Santo (**IK**)
Erronea (*Erronea*) *errones* Linné Espiritu Santo (**IK**)
Erronea (*Blasicrura*) *hirundo* Linné Espiritu Santo (**IK**)
Erronea (*Blasicrura*) *neglecta* Sowerby Espiritu Santo (**IK**)
Luria (*Basilitrona*) *isabella* Linné **NH** 5, **NH** 14, Espiritu Santo (**F, IK**), Vate (**F**), Tanna (**F**), Erromanga (**Hedley**), Aneiteum (**Hedley**)
Mauritia (*Arabica*) *arabica* Linné Tangoa, Espiritu Santo (**MCZ**), Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**), Vate (**F**), Erromanga (**Hedley**), Aneiteum (**Hedley**)
Mauritia (*Arabica*) *depressa* Gray New Hebrides (Schilder and Schilder, 1952)
Mauritia (*Mauritia*) *mauritiana* Linné Tangoa and Segond Channel, Espiritu Santo (**MCZ**), Espiritu Santo (**F, IK**), Vate (**F**), Erromanga (**Hedley**), Aneiteum (**Hedley**), Malekula (**CNHM**)
Monetaria annulus Linné **NH** 4, **NH** 5, **NH** 7, **NH** 8, **NH** 12, **NH** 13, **NH** 14, Tangoa and Segond Channel, Espiritu Santo (**MCZ**), Espiritu Santo (**F, IK**), Malekula (**CNHM**)
Monetaria moneta Linné **NH** 4, **NH** 13, Segond Channel, Espiritu Santo (**MCZ**), Erromanga (**Hedley**), Malekula (**CNHM**)
Nucleraria nucleus Linné Espiritu Santo (**IK**), Tanna (**F**), New Hebrides (**Hedley**)
Palmadusta asellus Linné Espiritu Santo (**IK**)
Palmadusta felina Gmelin Espiritu Santo (Schilder and Schilder, 1952)
Palmadusta fimbriata Gmelin Espiritu Santo (**IK**)
Palmadusta microdon Gray **F**
Pustularia childreni Gray Espiritu Santo (**F, IK**)
Pustularia cicerula Linné Espiritu Santo (**IK**), Aneiteum (**Hedley**)
Pustularia globulus Linné Tanna (**F**)
Pustularia mariae Schilder (=*annulata* Gray) Espiritu Santo (**IK**)
Staphylaea (*Staphylaea*) *limacina* Lamarck Espiritu Santo (**IK**)
Staphylaea (*Staphylaea*) *staphylaea* Linné Port Sandwich, Vate (Schilder and Schilder, 1952)
Talparia (*Arestorides*) *argus* Linné Espiritu Santo (**F**), Erromanga (**Hedley**), Aneiteum (**Hedley**)
Talparia (*Talparia*) *talpa* Linné Erromanga (**Hedley**)

Family CASSIDAE

Semicassis (*Casmarea*) *vibex* Linné Espiritu Santo (**F**), Vate (**F**)

Family CYMATIIDAE

Argobuccinum bituberculatum Lamarck Vate (**F**)

Charonia tritonis tritonis Linné Espiritu Santo (**F**)

Distorsio anus Linné Hirase and Taki (1951: pl. 96, fig. 4); **NH** 8, Espiritu Santo (**F**), Vate (**F**)

Gyrineum (*Gyrineum*) *natator* Röding (=*tuberculatum* Broderip) Man. Conch., (1)3: pl. 23, fig. 46; **NH** 9, **NH** 14

Gyrineum (*Gyrinella*) *pusillum* Broderip Man. Conch., (1)3: pl. 24, figs. 56, 57; **NH** 10

Lampusia chlorostoma Lamarck Man. Conch., (1)3: pl. 7, fig. 47; **NH** 9, Vate (**F**)

Lampusia rubecula Linné Espiritu Santo (**F**), Vate (**F**)

Ranularia (*Gutturnium*) *muricinum* Röding (=*nonulus* Link, *tuberosa* Lamarck) Vate (**F**)

Family BURSIDAE

Bursa bufonia Gmelin Man. Conch., (1)3: pl. 21, figs. 21, 23; **NH** 5

Bursa granularis Röding (=*affinis* Broderip) Vate (**F**)

Ranella (*Ranella*) *lampas* Linné Espiritu Santo (**F**)

Family TONNIDAE

Tonna (*Tonna*) *costatum* Menke New Hebrides (**F**)

Tonna (*Tonna*) *perdix perdix* Linné Hirase and Taki (1951: pl. 93, fig. 7); **NH** 14, Espiritu Santo (**F**), Tangoa, Espiritu Santo (**MCZ**), Erromanga (**Hedley**)

Family MURICIDAE

Aspella (*Favartia*) *tetragona* Broderip Man. Conch., (1)2: pl. 36, fig. 424; **NH** 9

Chicoreus (*Chicoreus*) *brunneus* Link (=*adustus* Lamarck) Hirase and Taki (1951: pl. 109, fig. 4); **NH** 8, **NH** 9, **NH** 12, **NH** 14

Cronia (*Usilla*) *margaritiicola* Broderip (=*undata* Chemnitz) Man. Conch., (1)2: pl. 59, fig. 260; **NH** 9, **NH** 13

Drupa (*Morula*) *anaxeros* Dunker Man. Conch., (1)2: pl. 57, fig. 219; **NH** 9

Drupa (*Morula*) *granulata* Duclos (=*tuberculata* Blainville) Hirase and Taki (1951: pl. 110, fig. 15); **NH** 13, New Hebrides (**F**), Immer (**Boettger**)

Drupa (*Drupina*) *grossularia* Röding (=*digitata* Lamarck) Vate (**F**)

Drupa (*Morula*) *marginatra* Blainville Kiener, *Purpura*, pl. 7, fig. 16; **NH** 8

Drupa (*Drupa*) *morum* Röding (=*horrida* Lamarck) Hirase and Taki (1951: pl. 110, fig. 8); **NH** 11, Cape Lisburn, Espiritu Santo (**H**), Vate (**F**)

Drupa (*Drupa*) *ricinus* Linné Hirase and Taki (1951: pl. 110, fig. 11); **NH** 14, Cape Lisburn, Espiritu Santo (**H**), Vate (**F**)

Drupa (*Drupa*) *rubuscaesium* Röding (=*hystrix* of authors) Hirase and Taki (1951: pl. 110, fig. 9); **NH** 14

Drupa (*Morula*) *uva uva* Röding (=*morus* Lamarck) New Hebrides (**Hedley**)

Drupa (*Morula*) *uva asperus* Lamarck Man. Conch., (1)2: pl. 57, figs. 215, 216; **NH** 4

Drupella elata Blainville Kiener, *Purpura*, pl. 10, fig. 27; **NH** 8, **NH** 9

Maculotriton digitalis Reeve Man. Conch., (1)3: pl. 15, figs. 142, 143; Aneiteum (**Hedley**)

Mancinella hippocastaneum Linné Demond (1957: 313, fig. 22); **NH** 5, **NH** 7, **NH** 8, **NH** 13, Vate (**F**), Immer (**Boettger**)

Mancinella intermedia Kiener Man. Conch., (1)2: pl. 45, fig. 41; **NH** 11

Mancinella tuberosa Röding (=*pica* Blainville) Man. Conch., (1)2: pl. 46, fig. 46; **NH** 1, **NH** 4

Murex (*Acupurpurea*) *ternispina* Lamarck Malekula (**F**)

Nassa sertum Bruguière (=*francolinus* Bruguière) Vate (**F**)

Thais (*Cymia*) *armigera* Link Hirase and Taki (1951: pl. 110, fig. 2); **NH** 11

Family MAGILIDAE

Coralliobia (*Quoyula*) *madreporarum* Sowerby Man. Conch., (1)2: pl. 47, figs. 389–391; Vate (**Hedley**)

Coralliophila violacea Kiener (=*neritoidea* of authors) Hirase and Taki (1951: pl. 111, fig. 8); **NH** 10

Family COLUMBELLIDAE

Columbella (*Columbella*) *obtusa* Sowerby Man. Conch., (1)5: pl. 59, figs. 65, 66; New Hebrides (**Hedley**)

Columbella (*Nitidella*) *testudinaria* Link (= *pardalina* Lamarck) Martini and Chemnitz, III(1d): pl. 6, figs. 8, 9; **ML** 41, **NH** 4, **NH** 7, **NH** 14, Nguna (**F**), Ambrym and Malekula (Hervier, 1899)

The typical form was found at ML 41 and NH 14; a variety (with slightly concave spire, orange-brown markings, and complete epidermis) which is near *vulpeca* Sowerby was found at NH 4 and NH 7.

Columbella (*Columbella*) *souverbiei* Crosse J. Conchyliol., 13: pl. 5, fig. 9; Vate (**F**), Tanna (**F**)

Columbella (*Columbella*) *versicolor* Sowerby Hirase and Taki (1951: pl. 107, fig. 1); **NH** 12, New Hebrides (**Mabille**)

Hervier (1899: 311) described a var. *hebridarum* from Ambrym Island.

Mitrella ligula Duclos New Hebridse (**Mabille**)

Pyrene discors Gmelin (?) **NH** 10

According to Pace (1902: 416) this is the most difficult group of Pacific Columbellidae. The identification is tentative.

Family BUCCINIDAE

Cantharus (*Pollia*) *fumosus* Dillwyn Demond (1957: 318, fig. 27); **NH** 1, **NH** 9, **NH** 13

Cantharus (*Pollia*) *undosus* Linné Demond (1957: 318, fig. 28); **NH** 9, **NH** 11, **NH** 13

Engina lauta Reeve Vate (**F**)

Engina lineata Reeve New Hebrides (**Mabille**)

Engina mendicaria Linné Hirase and Taki (1951: pl. 105, fig. 8); #5K, **ML** 41, **NH** 4, **NH** 9, **NH** 12, **NH** 13, Vate (**F**), Immer (**Boettger**)

Family NASSARIIDAE

Alectrion (*Alectrion*) *acuticosta* Montrouzier J. Conchyl., 12: pl. 10, fig. 8; **NH** 7, **NH** 9

Alectrion (*Zeuxis*) *lurida* Gould U. S. Explor. Exped. Wilkes, Atlas, fig. 325; **NH** 7, **NH** 9, **NH** 10

Alectrion (*Alectrion*) *monile* Kiener Kiener, *Buccinum*, pl. 11, fig. 40; **NH** 7, **NH** 9, **NH** 12, **NH** 13, **NH** 14, Vate (**F**)

Alectrion (*Zeuxis*) *mucronata* Adams Reeve, *Nassa*, pl. 2, fig. 8; **NH** 14

Alectrion (*Alectrion*) *ornata* Kiener Kiener, *Buccinum*, pl. 21, fig. 83; New Hebrides (**Mabille**)

Alectrion (*Zeuxis*) *pictus* Dunker Reeve, *Nassa*, pl. I, fig. 9; New Hebrides (**Mabille**)

Alectrion (*Zeuxis*) *siquijorensis* H. Adams Reeve, *Nassa*, pl. VIII, fig. 53; **NH** 10

Alectrion (*Zeuxis*) *taenia* Gmelin Vate (**F**)

Arcularia (*Arcularia*) *callospira* Adams Reeve, *Nassa*, pl. X, fig. 66; **NH** 12, New Hebrides (**Mabille**)

Arcularia (*Pliarcularia*) *globosa* Quoy and Gaimard Reeve, *Nassa*, pl. X, fig. 62; **NH** 1, **NH** 10, **NH** 12

Arcularia (*Arcularia*) *granifera* Kiener Man. Conch., (1)4: pl. 8, figs. 39–41; New Hebrides (**Hedley**)

Arcularia (*Pliarcularia*) *thersites* Bruguière Reeve, *Nassa*, pl. X, fig. 65; **NH** 9

Hebra muricata Quoy and Gaimard Reeve, *Nassa*, pl. XI, fig. 73; **NH** 11, New Hebrides (**Mabille**)

Hebra subspinosa Lamarck Kiener, *Buccinum*, pl. 26, fig. 103; **ML** 28, **NH** 7, Vate (**F**)

Hima (*Caesia*) *concinna* Powis Vate (**F**)

Hima (*Allanassa*) *eximia* H. Adams Adams (1872: pl. 3, fig. 28); New Hebrides (type locality)

Nassarius (*Nassarius*) *arcularia* Linné Reeve, *Nassa*, pl. IV, fig. 25; **NH** 5, **NH** 7, **NH** 12, Espiritu Santo (**F**), Vate (**F**)

Nassarius (*Phrontis*) *crassa* Koch Reeve, *Nassa*, pl. X, fig. 67; **NH** 7, **NH** 9, **NH** 12, **NH** 13, New Hebrides (**Mabille**)

Niothia albescens Dunker Reeve, *Nassa*, pl. XV, fig. 100; **NH** 7, **NH** 12, Vate (**F**, var. *bicolor* Hombron and Jacquinot)

Niothia gemmulata Lamarck (=*variegata* A. Adams) Reeve, *Nassa*, pl. XII, fig. 83; New Hebrides (**Mabille**)

Niothia pauperata Lamarck Philippi, Abbild. Besch. neu. Conch., *Buccinum*, pl. 2, fig. 18; **ML** 28, Vate (**F**)

Family FASCIOLARIIDAE

Fasciolaria coronata Lamarck Espiritu Santo (**F**)

Fasciolaria filamentosa Röding Hirase and Taki (1951: pl. 99, fig. 12); Tangoa, Espiritu Santo (**MCZ**)

Latirus polygonus Gmelin Hirase and Taki (1951: pl. 100, fig. 1); **NH** 9, **NH** 13, Vate (**F**)

Leucozonia (*Mazzalina*) *smaragdula* Linné Man. Conch., (1)3: pl. 70, fig. 185; **NH** 12, **NH** 13, **NH** 14, Vate (**F**)

Peristernia nassatula Linné Hirase and Taki (1951: pl. 100, fig. 5); **NH** 9, **NH** 11, **NH** 12, **NH** 5 contained a form with elongate spire

Family OLIVIDAE

Oliva (*Galeola*) *carneola* Gmelin Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *amethystina* Röding (=*guttata* Lamarck) Man. Conch., (1)5: pl. 19, figs. 64–74; Tangoa, Espiritu Santo (**MCZ**), New Hebrides (**Hedley**)

Oliva (*Oliva*) *irisans* Lamarck Espiritu Santo (**F**)

Oliva (*Oliva*) *ispidula* Linné Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *maura* Lamarck Espiritu Santo (**F**)

Oliva (*Oliva*) *miniacea* Röding (=*erythrostoma* Meuschen) Espiritu Santo (**F**), Erromanga (**Hedley**)

Oliva (*Oliva*) *mustelina* Lamarck **NH** 10 (juvenile)

Oliva (*Oliva*) *rubrolabiata* Fischer J. Conchyl., 50: 409–411, pl. 8, figs. 12, 13; Marmaram, Malekula (type locality)

Oliva (*Oliva*) *reticulata* Röding (=*sanguinolenta* Lamarck) Espiritu Santo (**F**)

Oliva (*Galeola*) *tessellata* Lamarck Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *tricolor* Lamarck New Hebrides (**Mabille**)

Family MITRIDAE

Imbricaria conica Schumacher Reeve, *Mitra*, pl. XXVII, fig. 216; **NH** 12

Imbricaria vanikorensis Quoy and Gaimard Hirase and Taki (1951: pl. 101, fig. 17); **NH** 14

Mitra (*Mitra*) *cardinalis* Gmelin Reeve, *Mitra*, pl. IV, fig. 26; **NH** 14

Mitra (*Mitra*) *mitra* Linné (=*episcopalis* Linné) Espiritu Santo (**F**)

Mitra (*Mitra*) *papalis* Linné Espiritu Santo (**F**)

Mitra (*Mitra*) *stictica* Link (=*pontificalis* Lamarck) Man. Conch., (1)4: pl. 32, fig. 3; Erromanga (**Hedley**)

Pterygia dactylus Linné Hirase and Taki (1951: pl. 101, fig. 16); **NH** 4

Pterygia fenestratus Lamarck Sowerby, Thes. Conch., IV, *Mitra*, fig. 363; New Hebrides (**Mabille**)

Pusia muriculatus Lamarck New Hebrides (**Mabille**)

Scabricula (*Chrysame*) *adusta* Lamarck Hirase and Taki (1951: pl. 101, fig. 3); **NH** 1

Scabricula (*Chrysame*) *aurantia* Gmelin New Hebrides (**Mabille**)

Scabricula (*Chrysame*) *chrysalis* Reeve Hirase and Taki (1951: pl. 101, fig. 2); **NH** 4, **NH** 9, **NH** 13

Scabricula (*Chrysame*) *tiarella* Adams (=*coronata* Lamarck, *non* Helbing) Reeve, *Mitra*, pl. XIV, fig. 104; **NH** 10, Vate (**F**)

Scabricula (*Chrysame*) *peregra* Reeve Surendo, Espiritu Santo (**F**)

Strigatella (*Strigatella*) *decurtata* Reeve Tangoa, Espiritu Santo (**MCZ**)

Strigatella (*Strigatella*) *litterata* Lamarck Hirase and Taki (1951: pl. 101, fig. 9); **NH** 8
Strigatella (*Strigatella*) *paupercula* Linné Reeve, *Mitra*, pl. XII, fig. 84; **NH** 9
Strigatella (*Strigatella*) *retusa* Lamarck Man. Conch., (1)4: pl. 46, fig. 343; **NH** 8, Vate (**F**)
Strigatella (*Strigatella*) *virgata* Lamarck Man. Conch., (1)4: pl. 46, fig. 341; **NH** 4, **NH** 8, **NH** 11
Vexillum (*Costellaria*) *cadaverosum* Reeve Reeve, *Mitra*, pl. XXI, fig. 160; **NH** 12
Vexillum (*Vexillum*) *gruneri* Reeve New Hebrides (**F**)
Vexillum (*Vexillum*) *plicarium* Linné Reeve, *Mitra*, pl. VIII, fig. 56; **NH** 4, New Hebrides (**F**)

Family VASIDAE

Vasum (*Vasum*) *ceramicum* Linné Vate (**F**)
Vasum (*Vasum*) *turbinellum* Linné Hirase and Taki (1951: pl. 99, fig. 9); **NH** 14, Espiritu Santo (**F**)

Family HARPIDAE

Harpa amouretta Röding (=*minor* Lamarck) Hirase and Taki (1951: pl. 112, fig. 13); **NH** 14, Espiritu Santo (**F**)
Harpa ventricosa Lamarck Malekula (**F**)

Family CYTHARIDAE

Daphnella pupoidea H. Adams Adams (1872: pl. 3, fig. 27); New Hebrides (type locality)

Family TURRIDAE

Ancistrosyrinx (=*Kenyonia*) *pulcherrima* Brazier Brazier (1896: 346); New Hebrides (type locality)
Clavus (*Tylotia*) *unizonalis* Lamarck (=*vidua* Reeve) Martini and Chemnitz, IV(3): pl. 13, fig. 1; **NH** 4, New Hebrides (**Mabille**)
Drillia auriculifera Lamarck Vate (**F**)
Philbertia philippinensis Reeve Reeve, *Pleurotoma*, pl. XIII, figs. 109a, b; **NH** 1
Philbertia picta rubroguttata H. Adams Adams (1872: pl. 3, fig. 25); New Hebrides (type locality)
Philbertia pulcherrima H. Adams Adams (1872: pl. 3, fig. 26); New Hebrides (type locality)
Turris (*Turris*) *picturata* Weinkauff Martini and Chemnitz, IV(3): pl. 2, fig. 10; **NH** 13

Family CONIDAE

Conus achatinus Gmelin Immer (**Boettger**)
Conus archiepiscopus Bruguière Kiener, *Conus*, pl. 96, figs. 1, 1a; **NH** 14, Malekula (**CNHM**)
Conus arenatus Bruguière Kiener, *Conus*, pl. 10, fig. 1; **NH** 12, Espiritu Santo (**F**)
Conus auratus Lamarck Man. Conch., (1)6: pl. 31, fig. 30; Erromanga (**Hedley**)
Conus catus Bruguière Kiener, *Conus*, pl. 43, figs. 1b, 1c (poor); **ML** 41, **NH** 14, Vate (**F**)
Conus ceylonensis var. **ML** 41 (worn)
Conus ceylonensis nanus Broderip Vate (**F**)
Conus chaldeus Röding (=*vermiculatus* Lamarck) Sowerby, Thes. Conch., III: pl. 189, fig. 53; **ML** 41, **NH** 9
Conus coronatus Gmelin (=*miliaris* Bruguière) Sowerby, Thes. Conch., III: pl. 194, fig. 278; **ML** 41, **NH** 4, **NH** 12, **NH** 14
Conus ebraeus Linné Hirase and Taki (1951: pl. 113, fig. 12); **ML** 41, **NH** 4, **NH** 5, **NH** 9, **NH** 12, Vate (**F**), Aore (**MCZ**), Immer (**Boettger**), Erromanga (**Hedley**)
Conus eburneus Bruguière Hirase and Taki (1951: pl. 113, fig. 15); **NH** 4, **NH** 12
Conus figulinus Linné Vate (**F**), Espiritu Santo (**F**)
Conus flavidus Lamarck Kiener, *Conus*, pl. 26, fig. 4; **NH** 4, **NH** 14
Conus geographus Linné Man. Conch., (1)6: pl. 28, fig. 84; Erromanga (**Hedley**)
Conus generalis Linné Kira (1955: pl. 36, fig. 21); Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**)
Conus litteratus Linné Hirase and Taki (1951: pl. 113, fig. 16); **NH** 4, Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**), Erromanga (**Hedley**)
Conus lividus Bruguière Kira (1955: pl. 37,

Nassarius (*Phrontis*) *crassa* Koch Reeve, *Nassa*, pl. X, fig. 67; **NH** 7, **NH** 9, **NH** 12, **NH** 13, New Hebrides (**Mabille**)

Niothia albescens Dunker Reeve, *Nassa*, pl. XV, fig. 100; **NH** 7, **NH** 12, Vate (**F**, var. *bicolor* Hombron and Jacquinot)

Niothia gemmulata Lamarck (=*variegata* A. Adams) Reeve, *Nassa*, pl. XII, fig. 83; New Hebrides (**Mabille**)

Niothia pauperata Lamarck Philippi, Abbild. Besch. neu. Conch., *Buccinum*, pl. 2, fig. 18; **ML** 28, Vate (**F**)

Family FASCIOLARIIDAE

Fasciolaria coronata Lamarck Espiritu Santo (**F**)

Fasciolaria filamentosa Röding Hirase and Taki (1951: pl. 99, fig. 12); Tangoa, Espiritu Santo (**MCZ**)

Latirus polygonus Gmelin Hirase and Taki (1951: pl. 100, fig. 1); **NH** 9, **NH** 13, Vate (**F**)

Leucozonia (*Mazzalina*) *smaragdula* Linné Man. Conch., (1)3: pl. 70, fig. 185; **NH** 12, **NH** 13, **NH** 14, Vate (**F**)

Peristernia nassatula Linné Hirase and Taki (1951: pl. 100, fig. 5); **NH** 9, **NH** 11, **NH** 12, **NH** 5 contained a form with elongate spire

Family OLIVIDAE

Oliva (*Galeola*) *carneola* Gmelin Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *amethystina* Röding (=*guttata* Lamarck) Man. Conch., (1)5: pl. 19, figs. 64–74; Tangoa, Espiritu Santo (**MCZ**), New Hebrides (**Hedley**)

Oliva (*Oliva*) *irisans* Lamarck Espiritu Santo (**F**)

Oliva (*Oliva*) *ispidula* Linné Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *maura* Lamarck Espiritu Santo (**F**)

Oliva (*Oliva*) *miniacea* Röding (=*erythrostoma* Meuschen) Espiritu Santo (**F**), Erromanga (**Hedley**)

Oliva (*Oliva*) *mustelina* Lamarck **NH** 10 (juvenile)

Oliva (*Oliva*) *rubrolabiata* Fischer J. Conchyl., 50: 409–411, pl. 8, figs. 12, 13; Marmaram, Malekula (type locality)

Oliva (*Oliva*) *reticulata* Röding (=*sanguinolenta* Lamarck) Espiritu Santo (**F**)

Oliva (*Galeola*) *tessellata* Lamarck Tangoa, Espiritu Santo (**MCZ**)

Oliva (*Oliva*) *tricolor* Lamarck New Hebrides (**Mabille**)

Family MITRIDAE

Imbricaria conica Schumacher Reeve, *Mitra*, pl. XXVII, fig. 216; **NH** 12

Imbricaria vanikorensis Quoy and Gaimard Hirase and Taki (1951: pl. 101, fig. 17); **NH** 14

Mitra (*Mitra*) *cardinalis* Gmelin Reeve, *Mitra*, pl. IV, fig. 26; **NH** 14

Mitra (*Mitra*) *mitra* Linné (=*episcopalis* Linné) Espiritu Santo (**F**)

Mitra (*Mitra*) *papalis* Linné Espiritu Santo (**F**)

Mitra (*Mitra*) *stictica* Link (=*pontificalis* Lamarck) Man. Conch., (1)4: pl. 32, fig. 3; Erromanga (**Hedley**)

Pterygia dactylus Linné Hirase and Taki (1951: pl. 101, fig. 16); **NH** 4

Pterygia fenestratus Lamarck Sowerby, Thes. Conch., IV, *Mitra*, fig. 363; New Hebrides (**Mabille**)

Pusia muriculatus Lamarck New Hebrides (**Mabille**)

Scabricula (*Chrysame*) *adusta* Lamarck Hirase and Taki (1951: pl. 101, fig. 3); **NH** 1

Scabricula (*Chrysame*) *aurantia* Gmelin New Hebrides (**Mabille**)

Scabricula (*Chrysame*) *chrysalis* Reeve Hirase and Taki (1951: pl. 101, fig. 2); **NH** 4, **NH** 9, **NH** 13

Scabricula (*Chrysame*) *tiarella* Adams (=*coronata* Lamarck, *non* Helbing) Reeve, *Mitra*, pl. XIV, fig. 104; **NH** 10, Vate (**F**)

Scabricula (*Chrysame*) *peregra* Reeve Surendo, Espiritu Santo (**F**)

Strigatella (*Strigatella*) *decurtata* Reeve Tangoa, Espiritu Santo (**MCZ**)

Strigatella (*Strigatella*) *litterata* Lamarck Hirase and Taki (1951: pl. 101, fig. 9); **NH** 8
Strigatella (*Strigatella*) *paupercula* Linné Reeve, *Mitra*, pl. XII, fig. 84; **NH** 9
Strigatella (*Strigatella*) *retusa* Lamarck Man. Conch., (1)4: pl. 46, fig. 343; **NH** 8, Vate (**F**)
Strigatella (*Strigatella*) *virgata* Lamarck Man. Conch., (1)4: pl. 46, fig. 341; **NH** 4, **NH** 8, **NH** 11
Vexillum (*Costellaria*) *cadaverosum* Reeve Reeve, *Mitra*, pl. XXI, fig. 160; **NH** 12
Vexillum (*Vexillum*) *gruneri* Reeve New Hebrides (**F**)
Vexillum (*Vexillum*) *plicarium* Linné Reeve, *Mitra*, pl. VIII, fig. 56; **NH** 4, New Hebrides (**F**)

Family VASIDAE

Vasum (*Vasum*) *ceramicum* Linné Vate (**F**)
Vasum (*Vasum*) *turbinellum* Linné Hirase and Taki (1951: pl. 99, fig. 9); **NH** 14, Espiritu Santo (**F**)

Family HARPIDAE

Harpa amouretta Röding (= *minor* Lamarck) Hirase and Taki (1951: pl. 112, fig. 13); **NH** 14, Espiritu Santo (**F**)
Harpa ventricosa Lamarck Malekula (**F**)

Family CYTHARIDAE

Daphnella pupoidea H. Adams Adams (1872: pl. 3, fig. 27); New Hebrides (type locality)

Family TURRIDAE

Ancistrosyrinx (= *Kenyonia*) *pulcherrima* Brazier Brazier (1896: 346); New Hebrides (type locality)
Clavus (*Tylotia*) *unizonalis* Lamarck (= *vidua* Reeve) Martini and Chemnitz, IV(3): pl. 13, fig. 1; **NH** 4, New Hebrides (**Mabille**)
Drillia auriculifera Lamarck Vate (**F**)
Philbertia philippinensis Reeve Reeve, *Pleurotoma*, pl. XIII, figs. 109a, b; **NH** 1
Philbertia picta rubroguttata H. Adams Adams (1872: pl. 3, fig. 25); New Hebrides (type locality)
Philbertia pulcherrima H. Adams Adams (1872: pl. 3, fig. 26); New Hebrides (type locality)
Turris (*Turris*) *picturata* Weinkauff Martini and Chemnitz, IV(3): pl. 2, fig. 10; **NH** 13

Family CONIDAE

Conus achatinus Gmelin Immer (**Boettger**)
Conus archiepiscopus Bruguière Kiener, *Conus*, pl. 96, figs. 1, 1a; **NH** 14, Malekula (**CNHM**)
Conus arenatus Bruguière Kiener, *Conus*, pl. 10, fig. 1; **NH** 12, Espiritu Santo (**F**)
Conus auratus Lamarck Man. Conch., (1)6: pl. 31, fig. 30; Erromanga (**Hedley**)
Conus catus Bruguière Kiener, *Conus*, pl. 43, figs. 1b, 1c (poor); **ML** 41, **NH** 14, Vate (**F**)
Conus ceylonensis var. **ML** 41 (worn)
Conus ceylonensis nanus Broderip Vate (**F**)
Conus chaldeus Röding (= *vermiculatus* Lamarck) Sowerby, Thes. Conch., III: pl. 189, fig. 53; **ML** 41, **NH** 9
Conus coronatus Gmelin (= *miliaris* Bruguière) Sowerby, Thes. Conch., III: pl. 194, fig. 278; **ML** 41, **NH** 4, **NH** 12, **NH** 14
Conus ebraeus Linné Hirase and Taki (1951: pl. 113, fig. 12); **ML** 41, **NH** 4, **NH** 5, **NH** 9, **NH** 12, Vate (**F**), Aore (**MCZ**), Immer (**Boettger**), Erromanga (**Hedley**)
Conus eburneus Bruguière Hirase and Taki (1951: pl. 113, fig. 15); **NH** 4, **NH** 12
Conus figulinus Linné Vate (**F**), Espiritu Santo (**F**)
Conus flavidus Lamarck Kiener, *Conus*, pl. 26, fig. 4; **NH** 4, **NH** 14
Conus geographus Linné Man. Conch., (1)6: pl. 28, fig. 84; Erromanga (**Hedley**)
Conus generalis Linné Kira (1955: pl. 36, fig. 21); Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**)
Conus litteratus Linné Hirase and Taki (1951: pl. 113, fig. 16); **NH** 4, Cape Lisburn, Espiritu Santo (**H**), Espiritu Santo (**F**), Erromanga (**Hedley**)
Conus lividus Bruguière Kira (1955: pl. 37,

fig. 2); **ML** 41, **NH** 5, Espiritu Santo (**F**), Vate (**F**)

Conus magus decurtatus Dautzenberg (=*adansoni* Sowerby, *non* Lamarck) Sowerby, Thes. Conch., III: pl. 199, figs. 286–289; **NH** 4, **NH** 9, **NH** 12, **NH** 14

Conus magus striolatus Kiener Kiener, *Conus*, pl. 105, fig. 1; **NH** 13

Conus marmoreus Linné Kira (1955: pl. 36, fig. 6): **NH** 4, **NH** 12, **NH** 14, Espiritu Santo (**F**), Vate (**F**)

Conus miles Linné Vate (**F**)

Conus omaria Bruguière Espiritu Santo (**F**)

Conus pulicarius Bruguière Kira (1955: pl. 36, fig. 15); **NH** 4, **NH** 12, Cape Lisburn, Espiritu Santo (**H**), New Hebrides (**F**)

Conus rattus Bruguière Kiener, *Conus*, pl. 44, fig. 3; **ML** 41, **NH** 8, **NH** 14

Conus senator Linné Vate (**F**)

Conus striatus Linné Kiener, *Conus*, pl. 47, figs. 1, 1a; **NH** 4, Erromanga (**Hedley**)

Conus tessellatus Born Man. Conch., (1)6: pl. 2, figs. 26, 27; New Hebrides (**Hedley**)

Conus textile Linné Aneiteum (Bennett, 1860)

Conus tulipa Linné Kira (1955: pl. 37, fig. 19); Segond Channel, Espiritu Santo (**MCZ**), Espiritu Santo (**CNHM**), Erromanga (**Hedley**)

Conus vautieri Kiener Espiritu Santo (**F**)

Family TEREBRIDAE

Terebra chlorata Lamarck Hirase and Taki (1951: pl. 116, fig. 8); **NH** 13

Terebra cingulifera Lamarck Nguna (**F**)

Terebra dimidiata Linné Nguna (**F**), Vate (**F**), Erromanga (**Hedley**), Aneiteum (**Hedley**)

Terebra felina Dillwyn (=*tigrina* Gmelin) Man. Conch., (1)7: pl. 1, fig. 11; New Hebrides (**Hedley**)

Terebra maculata Linné Kira (1955: pl. 38, fig. 21); **NH** 15, Nguna (**F**)

Terebra striata Quoy and Gaimard (=*affinis* Gray) Man. Conch., (1)7: pl. 2, figs. 18, 22; New Hebrides (**Hedley**)

Terebra strigilata Linné Man. Conch., (1)7: pl. 10, figs. 84, 85; Cape Lisburn, Espiritu Santo (**H**)

Terebra subulata Lamarck Vanua Lava (**F**)

DISCUSSION

The 409 species and varieties named above are not presumed to form a complete list of the fauna. The Hadfield collection of shells from Lifu in the Loyalty group contained 860 species, and subsequent research has added many more to that number. There are eight turrids known from the New Hebrides and 196 from New Caledonia. The 22 Mitridae listed here are only a fraction of the 151 reported from New Caledonia, and similar comparisons can be made for nearly every family.

Since I have prepared a similar checklist of the Solomon Islands marine shells (Solem, 1953, 1958), a tabular comparison of the known faunas might be instructive. From Table 1 it can be seen that only a little more than one half of the New Hebridean species have been reported from the Solomons, and that more than one half of the Solomon Islands species are not yet known from the New Hebrides. This is the result of inadequate collecting in both areas and does not indicate any great faunal difference between the two areas. It is quite possible that many Indonesian species reach the Solomons and not the New Hebrides, but almost all of the species listed in these papers are distributed extensively throughout most of the Indo-Pacific region. Their presence in the Solomons and New Hebrides is to be expected, but the scanty literature dealing with the marine

TABLE 1

COMPARISON OF KNOWN MARINE MOLLUSKS OF SOLOMON ISLANDS AND NEW HEBRIDES ISLANDS

GROUP	SPECIES		
	Common to both	In New Hebrides only	In Solomons only
Bivalves	36	61	65
Prosobranchs	183	121	245
Others	4	4	4
Totals	223	186	320

mollusks of Melanesia makes worthwhile the recording of distributional data for even common species. Of the 160 species collected by Kuntz, 89 (55.6 per cent) were previously unreported from the New Hebrides. It is probable that additional collections will contain a similar proportion of previously unrecorded species and that the total number of marine mollusks will be well over 2,000 species.

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A Key to the Chaetognatha of the Tropical Eastern Pacific Ocean

PAUL N. SUND[1]

THE INTER-AMERICAN Tropical Tuna Commission recently commenced a study of zooplankton collections from the tropical eastern Pacific Ocean to investigate the occurrence of planktonic organisms that can be used as biological indicators of water masses. This study is a part of the Commission's broader investigations of the relationship of the yellowfin and skipjack tunas and their food supply to the hydrographic regime within the eastern Pacific area.

The eastern tropical Pacific Ocean has been recently defined by Wooster and Cromwell (1958) as "the region lying between the Tropic of Cancer (23°27'N.) and the Tropic of Capricorn (23°27'S.) and extending westward from the coast of Central and South America to 130° W."

Two groups of animals which include species of known indicator value were selected for particular attention. These are the Euphausiacea and the Chaetognatha. The identities of the euphausiids were readily determined using the keys in the recent work of Boden, Johnson, and Brinton (1955). At the outset of our studies, the Chaetognatha proved to be quite difficult to identify because the published keys (e.g., Ritter-Zahony, 1911; Michael, 1908, 1911; Thomson, 1947) used characters that are often indistinguishable or whose determination is so time consuming that their use in studies of this sort was found impractical.

For these reasons it was decided to formulate a new key (of the type published by Fraser, 1952, for the chaetognaths of northern waters) that would allow rapid, but accurate, identification of a given specimen by using characters that are readily distinguishable in preserved animals of good-to-fair condition. General discussions of the characters and their use for purposes of identification are presented by Fowler (1904, 1906) and Michael (1908).

[1] Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, California. Manuscript received January 15, 1958.

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METHODS AND MATERIALS

The material was selected from the zooplankton collections made by University of California Scripps Institution of Oceanography research vessels during Eastropic Expedition, 1955. Figure 1 shows the locations of zooplankton stations from which the material for this study was taken. Holmes, Schaefer, and Shimada (1957) have outlined the methods and equipment employed in making these collections.

Specimens in good condition were identified and isolated from the Eastropic zooplankton. Upon accumulation of a number of these, the measurements and counts necessary to complete the armature formulae were made. All measurements were made with a calibrated ocular micrometer. These are presented in tabular form in the text, together with similar data obtained from specimens of known identity from eastern and central Pacific waters. The latter specimens were kindly donated to the writer by Dr. T. Tokioka of the Seto Marine Biological Laboratory, Japan; and Mr. T. Hida of Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Serv-

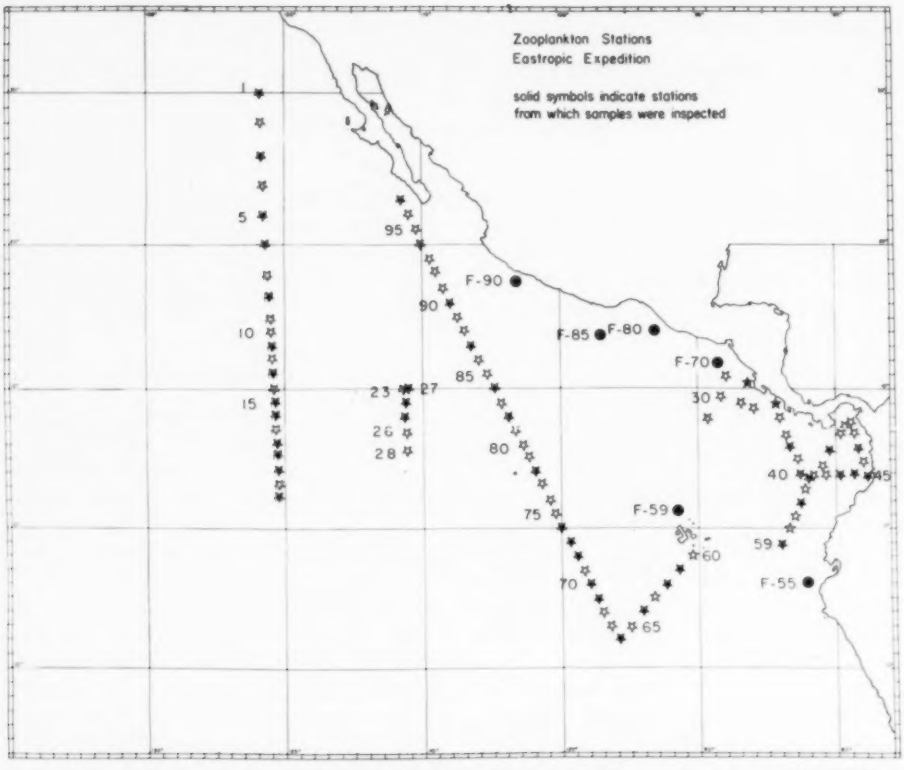


FIG. 1. Zooplankton stations occupied on Eastropic Expedition. Stars indicate stations occupied by RV Horizon; circles indicate those occupied by RV Spencer F. Baird. Modified from Holmes, Schaefer, and Shimada (1957).

ice, Honolulu, T. H. Of these, only those species represented in the Eastropic collections are considered in this publication. The armature formulae are included in this paper as they have been found useful in determining the variability within the limits of each species and in verifying the identity of juvenile and damaged specimens. For the measurements of the total length of the body and the tail segment, the caudal fin has been excluded as it is often damaged and its inclusion would lead to error.

DESCRIPTION OF THE SPECIES FOUND IN EASTROPIC COLLECTIONS

Several oceanographic investigations of the eastern Pacific have been made (Albatross, Dana, Discovery, and Shellback expeditions), but published works considering the Chaetognatha from the area are very few. Of the 36 species considered valid by Tokioka (1952), the following 18 species have been recorded by Baldasseroni (1915), Michael (1908, 1911), and Bieri (1957): *Sagitta bedoti*, *S. bipunctata = californica*, *S. decipiens*, *S. enflata*, *S. ferox*, *S. hexaptera*, *S. lyra*, *S. minima*, *S. neglecta*, *S. pulchra*, *S. regularis*, *S. robusta*, *S. serratodentata*, *S. tenuis*, *Krohnitta pacifica*, *K. subtilis*, *Eukrohnia hamata*, and *Pterosagitta draco*.

In addition to these species, *S. serratodentata pacifica* and *S. pseudoserratodentata* have been identified from the Eastropic material.

Sagitta bedoti Béraneck

S. bedoti, Bieri, 1957

Body firm, moderately opaque. Tail segment 17–27 per cent of total length of animal; hooks 6–7; anterior teeth 10–13; posterior teeth 20–29, or more. Anterior fins long, tapered, starting at ventral ganglion. Posterior and caudal fins close to, or touching, the seminal vesicles. Seminal vesicles oval. Intestinal diverticula absent. Collarette obvious.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
12.0	22.5	7	12	29
11.0	23.6	6	13	27
10.5	21.9	7	11	2[illegible]
9.9	21.2	7	10	24
8.3	26.5	7	11	27
7.4	22.9	7	10	20
Tokioka's specimens:				
10.4	23.2	6	11	28
9.5	21.1	7	12	28
8.5	17.7	6	10	23
7.9	24.0	7	10	22

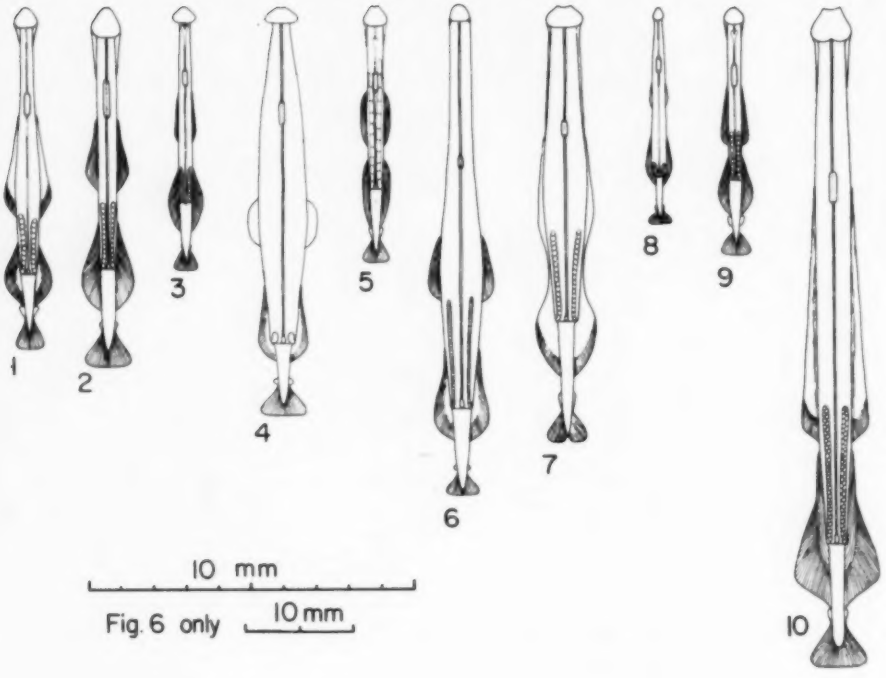
Sagitta bipunctata Quoy et Gaimard = S. californica Michael

S. bipunctata Michael, 1911
S. californica, Bieri, 1957

Bieri (1957) presents arguments supporting the change of the name of the species referred to by several workers as *S. bipunctata* to *S. californica*. Until this point is satisfactorily settled, I prefer to use the older name, *S. bipunctata;* but also to record that here, these two terms refer to the same single species.

Body firm, moderately opaque. Tail segment 21–28 per cent of total body length; hooks 5–10; anterior teeth 4–7; posterior teeth 8–14. Anterior fins start at posterior end of ventral ganglion. Posterior fins do not reach seminal vesicles; wider and slightly longer than anterior fins, widest behind tail-septum. Caudal fin joins seminal vesicles. Collarette present. No intestinal diverticula.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
16.3	27.6	8	4	8
11.0	24.5	10	7	14
9.3	21.5–24.7	5–9	4–5	9–12



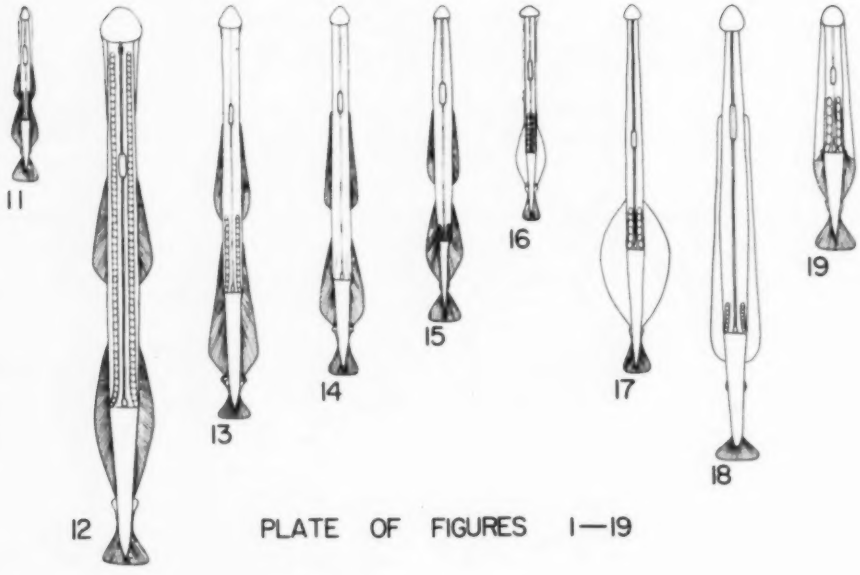


PLATE OF FIGURES 1—19

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
8.0	26.3	8	4	9
6.4	23.0	8	5	10
Tokioka's specimen:				
11.7	21.4	8	7	13
Hida's specimens:				
11.7	25.6	7	4	10
11.5	25.2	6	5	11
11.1	25.2	6	5	11
10.7	23.5–27.1	7–8	4–6	9

Sagitta decipiens Fowler, 1905

S. decipiens, Michael, 1908

Body delicate, moderately opaque. Tail segment 22–27 per cent of body length; hooks 5–7; anterior teeth 7–10; posterior teeth 13–20. Anterior fins start just posterior to ventral ganglion. Posterior fins widest at level of tail-septum, lying mostly on body segment, not reaching seminal vesicles. Caudal fin touching seminal vesicles. Intestinal diverticula present. Collarette absent.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
11.0	23.0	5	9–10	17
10.0	23.0	6	8	17
9.2	25.0	5	7	17
8.8	22.7–23.8	6–7	8–9	13–20
8.6	26.7	6	9	16

EXPLANATION OF PLATE I

(All figures drawn from preserved material, some with the aid of photographs; semidiagrammatic.)

FIG. 1. *S. bedoti*, 10.0 mm. specimen.
FIG. 2. *S. bipunctata*, 10.6 mm. specimen.
FIG. 3. *S. decipiens*, 7.8 mm. specimen.
FIG. 4. *S. enflata*, 12.6 mm. specimen.
FIG. 5. *S. ferox*, 7.6 mm. specimen.
FIG. 6. *S. hexaptera*, 44.9 mm. specimen. (Note change of scale.)
FIG. 7. *S. lyra*, 13.2 mm. specimen.
FIG. 8. *S. minima*, 6.5 mm. specimen.
FIG. 9. *S. neglecta*, 7.3 mm. specimen.
FIG. 10. *S. pulchra*, 19.7 mm. specimen.
FIG. 11. *S. regularis*, 5.1 mm. specimen.
FIG. 12. *S. robusta*, 17.0 mm. specimen.
FIG. 13. *S. serratodentata pacifica*, 12.5 mm. specimen
FIG. 14. *S. pseudoserratodentata*, 11.2 mm. specimen.
FIG. 15. *S. tenuis*, 9.5 mm. specimen.
FIG. 16. *K. pacifica*, 6.5 mm. specimen.
FIG. 17. *K. subtilis*, 11.2 mm. specimen.
FIG. 18. *E. hamata*, 13.6 mm. specimen.
FIG. 19. *P. draco*, 7.2 mm. specimen.

Sagitta enflata Grassi, 1883

S. enflata, Michael, 1908, 1911; Bieri, 1957
S. inflata, Baldasseroni, 1915

Body flaccid, transparent, with marked constriction at the tail-septum. Tail segment 14–18 per cent of total length; hooks 8–9; anterior teeth 4–10; posterior teeth 7–15. Anterior fins rounded, removed from ventral ganglion by a distance greater than the length of the fin, narrower than posterior fins. Posterior fins do not touch seminal vesicles, widest at level of tail-septum, or a little anterior. Caudal fin joining seminal vesicles. No collarette. No intestinal diverticula. Seminal vesicles round. Ovaries short.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
11.8	16.1	8–9	9–10	13
11.3	16.5	9	7	13
10.1	15.7	8	6	10
10.0	14.0	9	7	11
6.0	16.3	9	4	7
Hida's specimens:				
15.6	17.9	9	10	12
15.4	15.6	9	10	15
14.3	16.1	9	6	12
12.6	15.1	9	6	13
12.0	15.0	9	7	11

Sagitta ferox Doncaster, 1903

S. ferox, Bieri, 1957

Body firm, opaque, short and robust, of equal width for most of the length of body segment. Tail segment 22–28 per cent of total length; hooks 6–7; anterior teeth 6–13; posterior teeth 4–12. Anterior fins reach the posterior end of ventral ganglion. Posterior fins and tail fin close to, or touching, seminal vesicles. Posterior fins longer than anterior fins. Collarette present. Intestinal diverticula present; often removed from neck. Seminal vesicles angular, with anterior edge slanting postero-laterally. Ovaries when ripe containing cuboidal ova that fill body cavity.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
9.0	24.4	6	10	8
8.4	26.2	7	8	10
8.2	24.4	7	12	9
7.8	24.4	7	8	12

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
7.2	26.4	7	8	10
7.1	25.4	7	7–8	11
7.0	25.7	7	6–7	9
6.8	26.4	7	6	9
Tokioka's specimens:				
7.8	24.3	7	8	11
7.5	22.7–25.2	7	13	10
7.3	27.4	7	10	..
7.2	26.5	7	13	11
7.0	25.8	7	6	4

Sagitta hexaptera d'Orbigny, 1834

S. hexaptera, Michael, 1908, 1911; Baldasseroni, 1915; Bieri, 1957

Body large, transparent. Tail segment 15–22 per cent of total length of body; hooks 4–8; 1–4 anterior teeth; posterior teeth 1–4. Anterior fins widely separated from ventral ganglion; narrow and rounded. Posterior fins not joining seminal vesicles. Caudal fin close to, but not joining, seminal vesicles. Ovaries narrow, containing round ova, extending to posterior end of anterior fin when mature.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
44.5	15.7	6	3	..
23.7	17.8	7	3	4
19.0	19.0	7	3	4
Tokioka's specimens:				
34.8	19.8	4	3	2
34.6	18.8	2 (?)	1	1
23.5	21.3	6	3	1
22.3	19.3	7	4	2
14.3	20.9	7	3	3
Hida's specimens:				
36.5	18.4	8	2	3
31.4	18.8	6	2	3

Sagitta lyra Krohn, 1853

S. lyra, Michael, 1911; Baldasseroni, 1915; Bieri, 1957

Body large, flaccid, opaque. Tail segment 10–19 per cent of total length; hooks 6–10; anterior teeth 4–5; posterior teeth 2–9. Anterior fins reaching ventral ganglion, or further anterior; connected to the posterior fins by a "fin-bridge." Posterior fins close to, or touching, seminal vesicles. Caudal fin separated from seminal vesicles. Intestinal diverticula absent.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
29.1	10.3	9	5	6
29.0	13.1	10	5	7
25.8	14.7	10	5	9
25.0	14.8	10	4	6
21.2	16.5	9	5	7
19.8	17.7	10	..	..
16.0	17.8–18.8	10	4	6
Hida's specimens:				
41.5	12.1	6	4	5
40.0	13.3	8	5	2

Sagitta minima Grassi, 1881

S. minima, Bieri, 1957

Body small, transparent, with marked constriction at the tail-septum. Tail segment 16–24 per cent of total length; hooks 5–8; anterior teeth 2–5; posterior teeth 3–11. Anterior fins not rayed, narrow, tapered, but rounded; removed from ventral ganglion. Posterior fins not reaching seminal vesicles. Caudal fin connected to seminal vesicles. No intestinal diverticula. Ovaries short; when mature, they appear to contain 3–5 large, round ova.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
6.6	18.3	7	4	10
5.8	21.6	7	4	8
5.6	20.7	7	4	11
5.5	18.2–23.6	7–8	3–4	9–11
5.4	19.4–23.6	7–8	4	9–11
5.3	21.7	8	4	11
5.1	23.5	8	5	10–11
4.9	23.7	7	2	9
4.6	23.9	8	5	10–11
Tokioka's specimens:				
7.1	16.9	5	3	4
6.3	20.6	6	3	6

Tokioka's specimens:				
6.1	19.7	6	..	6
5.8	18.9	5	5	9
4.4	22.7	5	..	3

Sagitta neglecta Aida

S. neglecta, Michael, 1908; Baldasseroni, 1915; Bieri, 1957

Body firm, semiopaque. Tail segment 27–31 per cent of total length; hooks 6–8; anterior teeth 5–7; posterior teeth 13–17. Anterior fins start at ventral ganglion. Posterior fins reach seminal vesicles. Caudal fin separated from seminal vesicles by a distance equal to about ½ length of seminal vesicles. Seminal vesicles rounded. Ovaries containing rounded ova, extending anterior to posterior border of anterior fins. Collarette present. Intestinal diverticula present.

Few specimens of *S. neglecta* were found in the Eastropic material; only one of these was in such condition that a complete formula could be obtained.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimen:				
7.3	27.4	7	5	17

Sagitta pulchra Doncaster, 1902

S. pulchra, Michael, 1908; Baldasseroni, 1915; Bieri, 1957

Body firm, moderately opaque; usually slim, but can be robust and quite transparent; with a marked constriction often present at tail-septum as seen from side. Tail segment 16–24 per cent of total length; hooks 6; anterior teeth 5–9; posterior teeth 8–12. Anterior fins tapered, reaching posterior end of ventral ganglion. Posterior fins shortly separated from seminal vesicles; widest posterior to the tail-septum. Caudal fin joining seminal vesicles. Collarette present, readily visible. Intestinal diverticula absent. Seminal vesicles shaped as ovals; ovaries with small, round ova.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
20.3	16.3	6	7	12
20.0	16.5	6	7	9
19.5	16.4	6	9	11
16.7	18.0	6	8	10
14.9	17.5	6	7	9
13.9	18.7	6	6	11
10.1	19.8	6	7	10

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Tokioka's specimens:				
15.8	17.1	6	5	10
15.6	23.1	6	..	8
14.3	16.1	6	7	10
12.9	18.6	6	6	11
9.4	20.2	6	6	10
9.3	22.6	6	6	9
7.8	23.1	6	6	10

Sagitta regularis Aida, 1897

S. regularis, Bieri, 1957

Body firm, moderately opaque. Tail segment 29–34 per cent of total length; hooks 7–8; anterior teeth 2–4; posterior teeth 4–7. Anterior fins start at posterior end of ventral ganglion. Small interval between anterior and posterior fins. Posterior fins wider than anterior fins. Voluminous collarette usually present, covering head and most of body. No intestinal diverticula.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
5.8	32.8	7	3	5
5.6	32.1	8	4	6
5.3	32.1	8	3	5
5.2	30.8–32.7	7	3–4	4–6
5.1	31.4	8	4	7
5.0	32.0–34.0	7	2–4	4–5
4.8	29.2–31.3	7–8	3	5

Sagitta robusta Doncaster, 1903

S. robusta, Baldasseroni, 1915; Bieri, 1957

Body very opaque, firm; of uniform width from neck to tail-septum. Tail segment 24–28 per cent of total length; hooks 5–7; anterior teeth 6–11; posterior teeth 8–15. Anterior fins start at posterior end of ventral ganglion. Posterior and caudal fins both reaching seminal vesicles. Seminal vesicles long-tapered posteriorly. Ovaries long (when fully mature they may extend to the neck), containing eggs of moderate size. Intestinal diverticula present, but specimens are often too opaque for them to be seen.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
13.7	25.6	7	8	8

Eastropic specimens:				
13.6	28.0	6–7	7	12
13.2	27.3	7	10	14
12.7	26.0	5–7	10–11	14–15
12.5	25.6	6–7	10	13
9.5	26.3	6	9	12–13
9.3	28.0	7	6–7	10
8.6	25.6	6	11	12
Tokioka's specimen:				
16.4	26.6	6	8	8
Hida's specimens:				
13.0	26.9	6	9	14
11.9	24.4	7	10	12
11.1	27.0	6	8	13
10.0	27.0	7	8	12

Sagitta serratodentata pacifica Tokioka, 1940

S. pacifica, Bieri, 1957

The nomenclature employed for the *S. serratodentata* group is that suggested by Tokioka (1952). The synonyma are discussed by Furnestin (1953).

Body firm, opaque. Tail segment 22–25 per cent of total length; hooks 5–7; anterior teeth 5–11; posterior teeth 8–24. Anterior fins tapering, narrower than posterior fins; extending anteriorly to posterior end of ventral ganglion. Posterior fins widest behind tail-septum; close to, or touching seminal vesicles. Seminal vesicles greatly expanded anteriorly, armed laterally with 3–10 chitinous spines. Ovaries containing large cuboidal ova. Collarette small, or absent. Intestinal diverticula absent.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
12.5	23.2	6	10	17
12.4	22.5	6	11	23
11.4	22.0	6	10	19
10.8	24.0	5	8	19
10.6	23.5	6	9	20
10.5	22.9	..	8	15
10.0	25.0	6	7	15
9.6	20.8	7	8	13
Tokioka's specimens:				
13.0	23.5	5	7	13
12.4	23.4	5	9	18
12.2	23.0	7	9	18
12.0	24.2	6	9	17

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Tokioka's specimens:				
11.3	24.8	6	9	18
11.1	23.4	5	7	12–13
10.5	23.9	6	9	16
9.0	23.4	6	6	9
8.9	24.8	7	7	13
8.0	22.5	6	5	8
Hida's specimens:				
12.3	22.8	5	9	16
11.5	23.0	6	..	24
11.2	23.1	7	8	19
11.1	24.3	5	10	20
10.5	24.7	7	8	14

Sagitta pseudoserratodentata Tokioka, 1939

Tail segment 26–28 per cent of total length; hooks 6–7; anterior teeth 5–6; posterior teeth 7–12.

The features of this species are similar to those of *S. s. pacifica*, except that the seminal vesicles are unarmed, and the anterior edge of the vesicles slopes posterolaterally to a rounded point, from which the longer posterior border extends backwards and medially to rejoin the body wall. The percentage of the total length that the tail segment occupies is greater for specimens of equal size in *S. pseudoserratodentata* than in *S. s. pacifica*, and the number of teeth is less than in *S. s. pacifica* (see armature formulae tables).

S. pseudoserratodentata seems to be mature at a shorter total length than *S. s. pacifica*.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
7.1	26.7	6	5	9
6.8	26.5	7	5	7
6.2	27.4	6	6	12

Sagitta tenuis = friderici

S. tenuis Conant, 1896
S. friderici Ritter-Zahony, 1903
S. tenuis, Bieri, 1957

Body firm, translucent. Tail segment 21–26 per cent of total length; hooks 5–8; anterior teeth 2–5; posterior teeth 4–9. Anterior fins close to, but not reaching posterior end of ventral ganglion. Posterior fins close to, or touching seminal vesicles. Caudal fin reaching seminal

vesicles. Ovaries similar in appearance to those of *S. enflata*. Collarette present but extremely small; often missing in damaged specimens. Intestinal diverticula absent. Teeth wide-based, tapering sharply to a point; tips widely separated.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Tokioka's specimens:				
10.3	22.8	8	5	9
9.4	21.6	8	4	9
7.3	20.6	8	..	..
4.7	23.7	6	3	4
3.9	25.6	5	2	4

The formulae for *S. tenuis=friderici* identified from the Eastropic material have been omitted because the specimens were in such poor condition that accurate measurements could not be made. The specimens for which the formulae are given above were labelled by Tokioka as *S. friderici*. The status of the two species is still doubtful, especially concerning specimens from Pacific waters (Tokioka, 1955). The specimens so far identified from the Eastropic material were immature and in poor condition and provide no basis for a discussion of the validity of this species at this time. Bieri (1957) gives the impression that the two are synonymous, but his final interpretations must await the publication of his findings.

Krohnitta pacifica Aida, 1897

K. pacifica, Bieri, 1957

Body moderately firm, translucent-to-opaque. Single pair of lateral fins long and tapering; fins extend anteriorly from seminal vesicles over posterior ⅓ of trunk; widest behind septum. Collarette present, extending as narrow band from neck to anterior edge of fins. Tail segment 28–38 per cent of total length; hooks 6–9; teeth 7–15. Lateral and caudal fins joining seminal vesicles. Ovaries with cuboidal ova. Intestinal diverticula absent.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	TEETH
Eastropic specimens:			
7.2	31.9	7	11
6.8	33.8	7	13
6.6	31.8–31.9	7	13
6.4	35.9–37.5	7	14–15
6.3	30.1	7	12
Tokioka's specimens:			
7.1	28.1	9	12
7.0	28.6	9	12
4.2	31.0	6	7–8

Krohnitta subtilis Grassi, 1883

Eukrohnia subtilis, Michael, 1908, 1911

Body long, thin, moderately transparent, delicate. Tail segment 30–34 per cent of total length; hooks 5–8; teeth 8–12. Lateral fins wide, rounded, often subcircular; extending from seminal vesicles over posterior ⅓ of trunk; widest at level of tail-septum. Collarette and intestinal diverticula absent. Caudal fin touching seminal vesicles. Ovaries with rounded ova.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	TEETH
Eastropic specimens:			
12.5	32.0	7	11
10.2	31.3	7	11
10.0	30.0	8	12
Tokioka's specimens:			
11.3	34.1	6	8
10.6	32.0	6	9
10.2	32.4	5	9
9.1	34.0	6	..
Hida's specimens:			
10.9	30.0–32.0	7	9
10.4	31.2	7	11
9.2	30.5–31.2	7	11

Eukrohnia hamata Möbius, 1875

E. hamata, Michael, 1908, 1911

Body flaccid, opaque, wide. Single pair of lateral fins extending from behind tail-septum to ventral ganglion, not reaching seminal vesicles. Tail-septum 20–26 per cent of total length; hooks 8–9; single row of teeth, 6–17 in number. Tips of hooks curved inward. Intestinal diverticula absent. Collarette absent.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	TEETH
Eastropic specimens:			
10.7	23.4	8	17
7.0	22.9	8	6
Hida's specimens:			
13.9	21.5	9	10
13.7	25.5	9	9
13.2	20.5	9	6
10.7	23.4	9	6

Pterosagitta draco Krohn, 1853

Spadella draco, Michael, 1908, 1911
P. draco, Baldasseroni, 1915; Bieri, 1957

Body opaque, firm. Tail segment 32–38 per cent of total length; hooks 8–9; anterior teeth

4–9; posterior teeth 8–17. Single pair of lateral fins restricted to tail segment; wide, with rounded lateral borders; reaching seminal vesicles. Caudal fin close to, but not touching, seminal vesicles. No intestinal diverticula. Collarette voluminous, all or part frequently missing, extending from head to anterior border of fins, confluent with fins.

BODY LENGTH IN MM.	LENGTH OF TAIL SEGMENT (IN °/₀ OF TOTAL BODY LENGTH)	HOOKS	ANTERIOR TEETH	POSTERIOR TEETH
Eastropic specimens:				
7.1	35.2	8	6–7	12
5.8	36.2	8	6	15
5.6	37.8	9	6	15
5.1	37.2	9	6	17
4.9	32.6	8	5	13
4.4	38.6	9	6	8
4.0	35.0	9	4	..
Hida's specimens:				
7.6	34.2	9	9	15
6.9	34.7	9	9	17
6.8	35.2	9	7–8	11–14
6.3	36.6	9	7	..
6.2	37.0	9	7	17

KEY TO THE PLANKTONIC GENERA AND SPECIES OF CHAETOGNATHA PRESENT IN THE EASTERN TROPICAL PACIFIC

Key to the Genera of Chaetognatha

1. A single pair of lateral fins 2
1. Two pairs of lateral fins, which are sometimes connected ..... **Sagitta**
2. Two rows of teeth; one pair of lateral fins restricted to the tail segment, appearing as a continuation of a voluminous collarette (one species only: *P. draco*) ..... **Pterosagitta**
2. One row of teeth; one pair of lateral fins extending over the trunk and tail segments ... 3
3. Single pair of lateral fins extending from seminal vesicles over the posterior ⅓ of the trunk segment. Teeth long, tapered, tips converging ..... **Krohnitta**
3. Lateral fins slender, not reaching seminal vesicles, extending anteriorly to ventral ganglion. Teeth short, not converging (one species only: *E. hamata*) ..... **Eukrohnia**

Key to the Genus Krohnitta

1. Body slender, transparent; fins very wide, rounded, widest at level of tail-septum; short ovary with rounded ova; collarette absent ..... **subtilis**
2. Body robust, opaque; fins not rounded, widest behind tail-septum; ovaries contain large cuboidal ova; collarette sometimes evident as a narrow band of epidermal thickening extending from neck to anterior edge of fins ..... **pacifica**

Key to the Genus Sagitta

1. Anterior fins start some distance posterior to ventral ganglion 2

1. Anterior fins start at level of posterior end of ventral ganglion, or farther anterior 7
2. Lateral fins joined by "fin bridge"; caudal fin bilobed . . . . . **lyra**
2. Lateral fins not joined 3
3. Anterior fins rounded, widely separated from ventral ganglion 4
3. Anterior fins tapering; distance between anterior fins and ventral ganglion not great (distance is less than that equal to a length of the ventral ganglion) 5
4. Teeth numerous; hooks 8–10; small-to-middle size species . . . . . **enflata**
4. Teeth few, protruding; large species . . . . . **hexaptera**
5. Moderately opaque species; delicate, of medium length; intestinal diverticula present . . . . . **decipiens**
5. Small, transparent species; no intestinal diverticula 6
6. Tail segment tapers sharply posterior to tail-septum, marked constriction at septum; 3–5 large, round ova in mature specimens; lateral septa connecting gut to body wall sometimes evident; posterior fins widely separated from seminal vesicles . . . . . **minima**
6. Constriction at tail-septum not great; ovaries club-shaped; posterior fins close to, but not touching, seminal vesicles; caudal fins touching seminal vesicles . . **tenuis = friderici**
7. Posterior fins joining, or close to seminal vesicles 8
7. Posterior fins not joining seminal vesicles; no intestinal diverticula; seminal vesicles head-shaped anteriorly; 9–10 hooks . . . . . **bipunctata**
8. Voluminous collarette covering head and most of body . . . . . **regularis**
8. Collarette not covering head 9
9. Posterior teeth less than 20; intestinal diverticula may, or may not be present 10
9. Posterior teeth 20–30; intestinal diverticula absent; anterior fins tapering, reaching ventral ganglion; collarette obvious . . . . . **bedoti**
10. Intestinal diverticula absent 11
10. Intestinal diverticula present 13
11. Posterior fins shorter than anterior fins; widest behind tail-septum; collarette of moderate size; anterior fins tapering, reaching ventral ganglion; hooks 6; posterior teeth 8–12 . . . . . **pulchra**
11. Posterior fins longer than anterior fins, or of about same length 12
12. Posterior fins widest well behind tail-septum, jaws serrated, 6–7 in number . . . . . **serratodentata** group
    a. Posterior fins close to seminal vesicles; seminal vesicles armed with spines anterolaterally, sometimes with a membrane connecting the anterior free end to the body; short space separating caudal fin and seminal vesicle; 12–15 mm. maximum length when mature . . . . . **S.s. pacifica**
    b. Seminal vesicle triangular in shape, anterior border slants posterolaterally; 10–12 mm. maximum length when mature; (common in California current) . . . . . **S. pseudoserratodentata**
13. Seminal vesicles close to but not in contact with caudal fin, separated by distance equal to about ½ length of seminal vesicle . . . . . **neglecta**
13. Seminal vesicles touch caudal fin 14
14. Body very opaque, of uniform width from neck to tail-septum; collarette extends from neck to anterior fins; ovaries extending to neck, containing eggs of moderate size; intestinal diverticula not obvious due to opacity of species . . . . . **robusta**
14. Body moderately transparent, of uniform width from ventral ganglion to tail-septum; ovaries containing large eggs that fill body cavity; intestinal diverticula obvious . . **ferox**

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Notes on Indo-Pacific Scleractinian Corals
Parts I and II

Part I. *Oryzotrochus*, a New Genus of Turbinolian Coral

JOHN W. WELLS[1]

IN 1954 the writer spent a few days studying part of the coral collections of the Australian Museum. Among much undetermined material was a lot consisting of two species of very small turbinolian corals from a dredge haul (source unknown) made at the northern end of the Great Barrier Reef. One species was *Holcotrochus scriptus* Dennant 1902, a most peculiar form previously recorded only from the Lower Miocene and Pliocene of South Australia and from depths of 38–185 meters off South Australia. It was represented by some 20 individuals, 1 of which is illustrated in Figures 6 and 7. The other species, represented by 100 specimens, mostly more or less damaged, proved to be a new turbinolian genus, here called *Oryzotrochus* in allusion to its resemblance to a rice grain.

Special thanks are due to F. J. McNeill of the Australian Museum for permission to retain several specimens for description.

Family CARYOPHYLLIIDAE

Subfamily *TURBINOLIINAE*

Oryzotrochus gen. nov.

Small, solitary, free, conical corals. Wall imperforate, externally costate with prominent, high, smooth costae. Septa exsert, smooth margined, lightly granulated laterally. Pali absent. Columella small and styliform.

This genus is obviously very closely allied to the well-known Tertiary (Eoc.-Mioc.) genus *Turbinolia*,[2] from which it is distinguished only by the absence of mural perforations or external intercostal pits. The more apparent differences from other conical turbinolians are brought out in the following artificial key.

A. Wall perforate or with deep intercostal pits:
  1. Pali absent:
    a. Columella spongy ..... **Bothrophoria** Felix (U. Cret.)
    b. Columella styliform:
      aa. Costae smooth ..... **Turbinolia** Lamarck (Eoc.-Mioc.)
      bb. Costae hispid ..... **Batotrochus** Wells (Rec.)
  2. Pali present:
    a. 1 crown of 6 before second cycle; costae smooth ..... **Conocyathus** d'Orbigny (Eoc.-Rec.)
    b. Pali weakly developed; costae hispid ..... **Trematotrochus** Tenison-Woods (Olig.-Rec.)
B. Wall imperforate:
  1. Paliform lobes absent ..... **Oryzotrochus** n.g. (Rec.)
  2. Paliform lobes present ..... **Notocyathus** Tenison-Woods (Eoc.-Rec.)

[1] Department of Geology, Cornell University, Ithaca, N. Y. Manuscript received February 17, 1958.

[2] *Turbinolia australiensis* Gardiner 1939 (*Discovery Reports*, vol. 18, p. 332, pl. 21, figs. 1, 2), from Port Jackson, N. S. Wales, is *Conocyathus zelandiae* Duncan 1876.

Type species: ***Oryzotrochus stephensoni*** n. sp.

Oryzotrochus stephensoni sp. nov.

Figs. 1–5

With the characters of the genus as diagnosed above. Septa 12 in number, in two cycles, thin, upper margins evenly arched and equally exsert over the wall and dropping steeply to level of the columella about halfway between wall and axis. Septa generally all extending to and fusing with the columella, but secondaries in one or two systems may join primaries short of the columella. Costae corresponding to all septa, equal, high, smooth-margined, separated by relatively broad and flat interspaces. An irregular row of very small buttresslike expansions on each side of each costa at junction with the wall. Primary costae distinct to the base; secondary costae arising just short of the base. Columella a slender style elevated about to height of exsert septal margins.

Dimensions

	HEIGHT	CALICULAR DIAMETER	
Holotype	3.5 mm.	1.7	(Figs. 3, 4)
Paratype	3.0	1.5	(Fig. 5)
Paratype	3.3	1.6	(Fig. 1)
Paratype	2.4	1.5	(Fig. 2)

Named for W. Stephenson, Professor of Zoology, University of Queensland.

Holotype and figured paratypes to be deposited in the U. S. National Museum. Remaining paratypes are in the Australian Museum.

Locality

Murray Islands (9°55′S., 144°02′E.), near northern end of Great Barrier Reef, Queensland, 9–15 meters.

Part II. A New Species of *Turbinaria* from the Great Barrier Reef

AT LEAST 350 species representing 57 genera of reef-building scleractinian corals are now known from the Great Barrier Reef area (Wells, 1955: 21). It would seem ungracious to add a new species to this burdensome total, especially to a genus with 34 species already reported from this region, many of them of doubtful validity, but the form described below is so distinct that it cannot be referred to any known species of *Turbinaria*.

Family DENDROPHYLLIIDAE

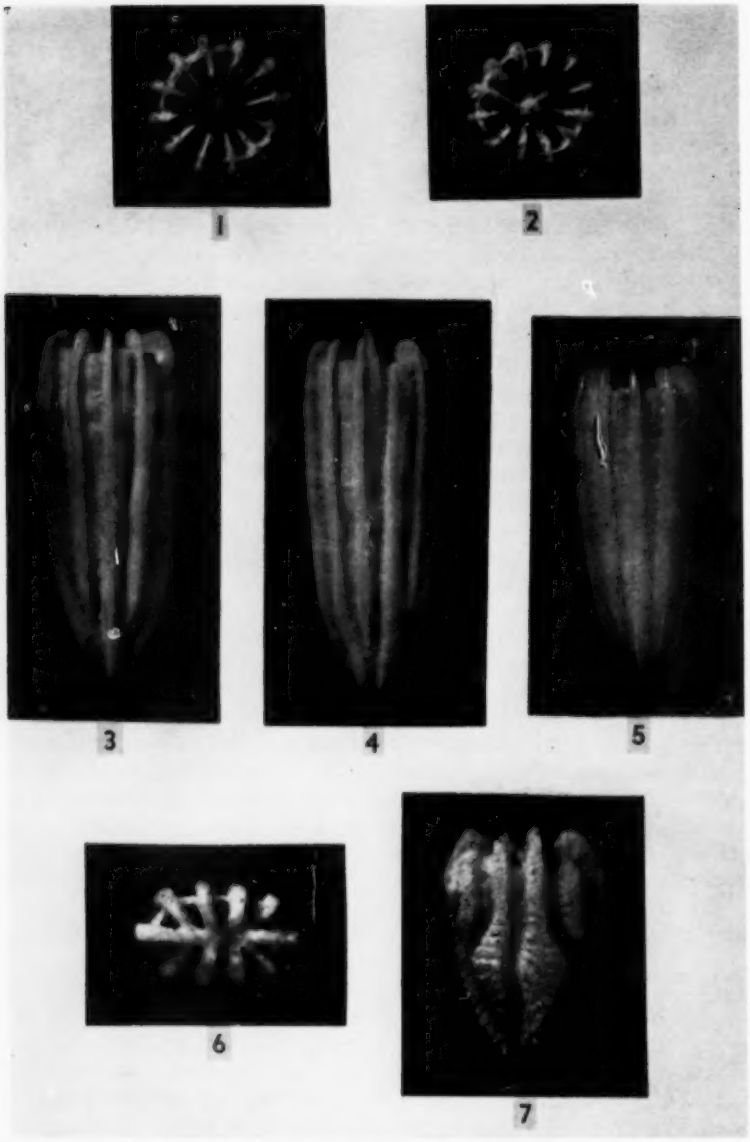
Genus TURBINARIA Oken 1815

Turbinaria beronensis sp. nov.

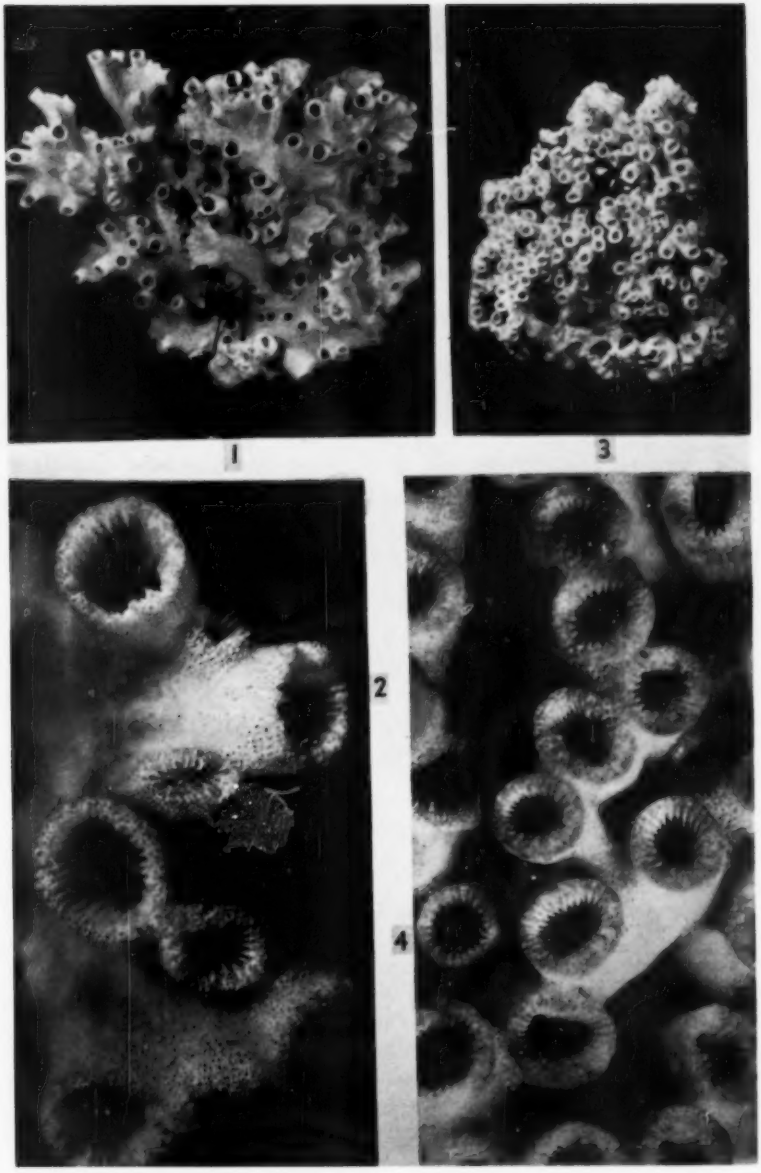
Figs. 1–4

Corallum bushy, to 20 cm. in height, formed by erect branches arising from a small, encrusting base. Corallites tending to develop irregularly on opposite sides of flattened and twisted branches, new extratentacular buds appearing in the plane of the branches between the previously formed and the next previously formed corallites. Corallites cylindrical, rarely more than 10 mm. long without buds, averaging 4 mm. in diameter. Wall spongy. Calices deep (3 mm.), circular, averaging 3 mm. in internal diameter. Septa thick peripherally in the wall, thin axially, upper margins dropping abruptly to the level of the columella, 36 to 40 in number, irregularly arranged, with 24 to 30 extending to the columella, the remainder fusing to lower cycles of septa. Columella a deep, chicoraceous, trabecular column about half the internal diameter of the corallites. Coenosteum and exterior of free parts of corallites very compact but porous, the surface appearing smooth, but very finely vermiculo-echinulate.

This species is readily distinguished from practically all other known recent species of



FIGS. 1–5. *Oryzotrochus stephensoni* n. gen., n. sp. 1, 2, Calicular aspect of two paratypes. 3, 4, Lateral aspects of holotype. 5, Lateral aspect of paratype. 6, 7, *Holcotrochus scriptus* Dennant. Calicular and lateral aspects. (All figures 15×.)



FIGS. 1, 2. *Turbinaria heronensis* n. sp. 1, Lateral aspect of holotype corallum, × 0.4. 2, Calices of same, × 4. 3, 4. *T. heronensis*. 3, Calicular aspect of rough-water facies (paratype), × 0.4. 4, Calices of same, × 4.

Turbinaria by its subramose growth form. The growth form in *Turbinaria* is characteristically crateriform to foliate, with barely protuberant corallites. The only other subramose species is *T. ramosa* Yabe and Sugiyama (1941, p. 89, pl. 100, figs. 2, 2a, 2b) from Kyushu, Japan, but in this species the corallites taper slightly toward the calice, the calices are slightly smaller (2.5–3 mm.) with only 14 to 16 thick, wedge-shaped septa, and the columella is sublamellar. The most significant difference lies in the smaller number of septa in the Japanese coral. There is a slight resemblance to the allied genus *Duncanopsammia* in the calicular characters and even less in the mode of growth.

The typically loosely ramose form (Fig. 1) of *T. heronensis* grows in relatively sheltered sites amongst other corals on reef flats. Stunted, compact, fasciculate colonies (Fig. 3) are occasionally found in rough-water environments near reef margins. The polyps are an unpleasant sulphur yellow, set in yellow-brown coenosarc.

A number of specimens of this coral have been seen in collections from the Great Barrier Reef, but very few had definite localities. The living specimens were collected by the writer in 1954 at Heron Island, Queensland. Holotype and figured paratype are to be deposited in the U. S. National Museum.

Localities

Great Barrier Reef, Queensland; windward reef flat, Heron Island (23° 25′ S.), Capricorn Group (holotype); windward reef margin, Heron Island (paratype: rough-water facies); Low Isles (16° 25′ S.) (Australian Museum): South Molle Island (20° 15′ S.), Whitsunday Group (in private collection at S. Molle); "East of Port Curtis" (probably from Capricorn or Bunker Group, 23° 30′ S.) (Australian Museum No. 4955).

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Occurrence of Gibbsite Amygdules in Haiku Bauxite Area of Maui[1]

G. Donald Sherman and Haruyoshi Ikawa[2]

Areas of bauxite deposits have been discovered on the islands of Kauai, Maui, and Hawaii of the Hawaiian Islands. These deposits have been described by Sherman (1957) and Fellom (1957). In many of these deposits the free aluminum oxide occurs as a constituent of irregular-shaped nodules varying in size from 1/100 inch to over 6 inches in their longest dimensions. The alumina content of these nodules as determined in the laboratories of the Hawaii Agricultural Experiment Station ranges from 40 per cent to 62 per cent. Iron oxide was found to be the other major constituent of these nodules ranging from a little over 2 per cent to 40 per cent. Mineralogical analysis of the nodules has identified the minerals as gibbsite, the trihydrate of aluminum oxide, and goethite, an iron oxide.

Recently, layers of pea-sized gibbsite amygdules were found in several of the deep road-cuts occurring on the new highway to Hana, 3–5 miles east of Pauwela, Maui. The white gibbsite amygdules are exposed in the banks of the road-cuts as irregular layers from 12 to 20 feet below the surface soil. These layers are easily recognized because the numerous white amygdules occur in dark gray brown rocks which are completely weathered. These weathered rocks still retain the structure of the original parent rock. The material is soft and when crushed between one's fingers it readily breaks down to a clayey material, and the hard round amygdules. The amygdules are shown in Figure 1.

A close examination of the amygdules revealed that they have been developed by the precipitation of hydrated aluminum oxide in the cavities of the parent rock. The unfilled cavities can be found in adjacent parent rock and in the unweathered rock of the same formation. The cavities were formed by gas bubbles in the original lava. The precipitation of the aluminum oxide initially occurred on the wall of the cavity. Subsequent precipitation of additional aluminum oxide has continued until the cavity was completely filled. The contents of the cavity harden to form a resistant amygdule. The size and shape of the cavity determine the physical shape of the amygdule. The aluminum is transported in percolating waters to the cavity as aluminum hydroxide and is precipitated as the hydroxide on exposure to air in the cavity. It then is converted to trihydrate of aluminum oxide on aging in a drier atmosphere. The evidence for the mode of deposition of the aluminum oxide in the cavities is as follows: (a) the occurrence of similar unfilled cavities having similar shapes and volume in the adjacent weathered material, (b) the concentric deposition layers of the amygdule, (c) the occurrence of hollow amygdules which would indicate the initial precipitation of the hydrated oxide on the wall of the cavity (several of the amygdules in Fig. 1 have hollow centers), and (d) the observation of the formation of aluminum and iron oxides on exposure of seepage waters exuding from ditch and road cuts during the wet season.

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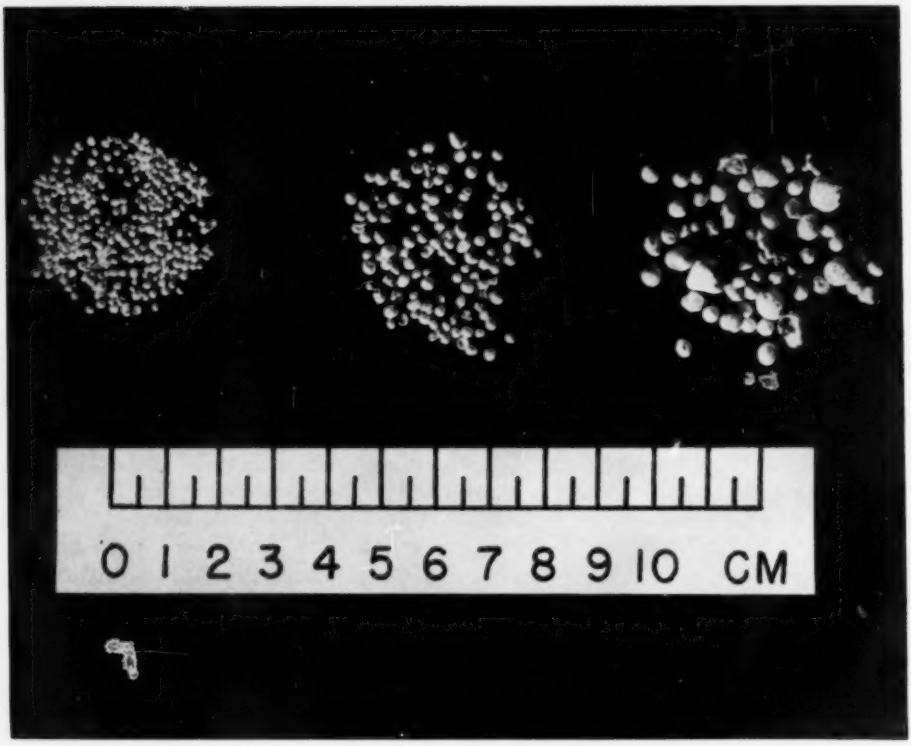

FIG. 1. Samples of gibbsite amygdules from Haiku bauxite area east of Pauwela, Maui. Samples on the right show outer skin of amygdule, some of which are hollow in the center.

Samples of the weathered rock containing the amygdules were collected to determine their chemical and mineral compositions. The amygdules were separated by dry-screening on a 20-mesh sieve and then any adhering matrix was removed by washing with distilled water. The samples of matrix and amygdules were dried and weighed. The chemical analysis of the samples of matrix and amygdules was made by procedures described by Piper (1944). The identification of the minerals in both the matrix and the amygdules was made by differential thermal analysis procedures proposed by Norton (1939). The samples were ground to pass through a 100-mesh sieve before analysis.

The chemical composition of the amygdules and their respective matrices is presented in Table 1. The samples of amygdules have a very uniform chemical composition which averages as follows: 1.6 per cent SiO_2; 61.7 per cent Al_2O_3; 5.8 per cent Fe_2O_3; 0.8 per cent TiO_2; and, a loss on ignition of 30.9 per cent. The chemical composition of the amygdules approaches that of the mineral gibbsite, the trihydrate of aluminum oxide. The theoretical analysis of gibbsite is approximately 66 per cent Al_2O_3 and a loss on ignition of 34 per cent. The average composition of the matrix is as follows: 2.5 per cent SiO_2; 27.9 per cent Al_2O_3; 44.0 per cent Fe_2O_3; 9.6 per cent TiO_2; and a loss of ignition of 15.0 per cent. The variation in chemical analysis of the samples of amygdules and matrix is

extremely uniform. The remarkable fact brought out by the analyses is that the amygdules have a high concentration of aluminum oxide while the matrix has a high concentration of iron and titanium oxides. The silica content of both materials is very low. This same observation has been made in other types of precipitation of gibbsite from percolating waters.

The data presented in Figure 2 were obtained from the differential thermal analysis of a representative sample of the amygdules and the matrix. The strong endothermic peak occurring in these curves at temperatures between 350° C. and 375° C. is due to the minerals gibbsite and goethite. The endothermic action of gibbsite is much stronger than goethite, thus it is safe to identify the aluminum oxide mineral of the amygdule as gibbsite, the trihydrate of aluminum oxide.

The occurrence of gibbsite amygdules in the Hawaiian bauxite deposits is of considerable interest. Prior to their discovery, the gibbsite had been found only in nodular form and in sheets of aluminum oxide with iron oxide in seepage channels of percolating water. Pisolitic deposition of gibbsite has been described by Alexander *et al.* (1955). In the soils above the decomposed layer, the amygduloidal gibbsite occurs in aggregates and thus might easily be described as being a pisolitic occurrence of gibbsite.

They observed gibbsite fills in spaces left by shrinkage in the hardening of laterite. The recently discovered bauxite of Cape York, Australia, is a pisolitic type of concentration. Its development has been attributed to the flooding of the coastal areas during the cyclones of the monsoon season and its subsequent drying. The development of pisolites

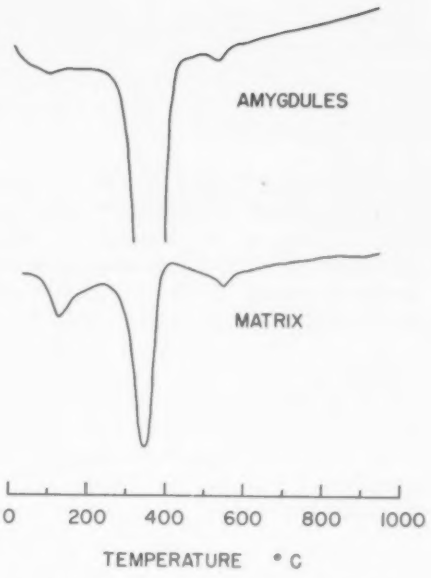

FIG. 2. The representative differential thermal analysis curves of a sample of amygdule and the matrix. Amygdules are from the Haiku bauxite area east of Pauwela, Maui.

TABLE 1
THE CHEMICAL COMPOSITION OF GIBBSITE AMYGDULES AND THEIR MATRICES FROM THE HAIKU BAUXITE AREA EAST OF PAUWELA, MAUI
(Samples from road-cuts on Hana road)

SAMPLES	SAMPLE PER CENT	SiO_2 PER CENT	Al_2O_3 PER CENT	Fe_2O_3 PER CENT	TiO_2 PER CENT	LOSS ON IGNITION PER CENT
Amygdules A	51.1	1.54	61.72	5.64	0.80	30.96
Matrix A	48.9	2.43	28.68	45.37	9.43	15.11
Amygdules B	49.5	1.65	61.60	5.83	0.73	31.06
Matrix B	50.5	2.65	27.80	46.30	9.62	14.92
Amygdules C	50.4	1.72	61.72	6.08	0.88	30.60
Matrix C	49.6	2.52	27.24	46.42	9.62	14.84

and amygdules of gibbsite depends upon wet and dry conditions to provide the means of movement of the alumina in order to produce the rhythmic precipitation which is so characteristic of their structure.

SUMMARY

The occurrence of gibbsite amygdules in a bauxite deposit of the Haiku area of Maui has been described. The amygdules are formed by the rhythmic precipitation of hydrated aluminum oxide in cavities which are relics of the parent rock. These cavities were probably gas bubbles in the original lava. The amygdules contain approximately 62 per cent Al_2O_3, 6 per cent Fe_2O_3, and trace amounts of silica and titania. The hydrated aluminum oxide has been identified as gibbsite by differential thermal procedures.

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A Survey for Alkaloids in Hawaiian Plants. I

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and PAUL J. SCHEUER[1]

ALTHOUGH PLANT ALKALOIDS have been isolated and studied for over 150 years, only a small percentage of the recorded plant species have been investigated and even fewer of the isolated compounds have been carried to full elucidation of their structures. Willaman and Schubert (1955) in their valuable survey of alkaloid-containing plants state that by the end of 1952 about 950 alkaloids were isolated and named and that 1,202 plant species were known to contain alkaloids. Up to that time only about 2 per cent of all recorded plant species had been as much as tested for alkaloids.

The widely varying pharmacological properties of alkaloids always have been a major point of interest and have helped to attract organic chemists to this field of research. This viewpoint, however, was losing ground steadily in the face of mounting successes scored by synthetic drugs. The demonstration by Müller, Schlittler, and Bein (1952) that the alkaloid reserpine was responsible for the hypotensive action of the Indian snakeroot, *Rauvolfia serpentina* Benth., instilled new vigor into natural products research. As a consequence of this work many members of the genus *Rauvolfia* and related genera in the plant family Apocynaceae from all parts of the tropics have been investigated. This recent research has also prompted the chemical study of three of the reported seven Hawaiian *Rauvolfia* species (Gorman *et al.*, 1957).

In order to utilize plant sources for the isolation of alkaloids effectively it is necessary to survey a given flora, and base subsequent detailed work on the results of such a survey. A number of native floras have been investigated in recent years from this point of view. The most notable of these have been carried out in Australia (Webb, 1949, 1952), and more recently in Papua–New Guinea (Webb, 1955).

Hawaii's flora is unique in two respects: It offers widely diverse vegetational types located within small geographical areas, and its native flora is over 90 per cent endemic, one of the highest endemisms in the world. Yet, except for the recent *Rauvolfia* research (Gorman *et al.*, 1957) and a few isolated instances in the past (e.g., Folkers and Koniuszy, 1939), Hawaii's flora has not been the subject of chemical study, nor has it even been surveyed for alkaloids. The pioneering research of Bushnell and co-workers (1950) drew attention to the antibacterial properties of some plants found in Hawaii and to the important link between Hawaiian flora and native Hawaiian *materia medica*.

The present work is concerned with a survey of some Hawaiian plants for their alkaloid content. While the 96 species tested represent only a small fraction of the recorded species, it is hoped that this work will constitute only the beginning of more extensive surveys in the future.

METHODS

This study was patterned after the survey carried out by Webb (1949, 1952) in Australia. The floristic books by Hillebrand (1888) and by Rock (1913) were used in the study of the indigenous plants of Hawaii. An attempt was made to test indigenous plants predominantly, although some introduced species have been included. A majority of the tests were carried out on freshly collected specimens. To ascertain that herbarium speci-

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mens gave valid results, several cross checks were made. All identifications of plants were made by H. St. John.

EXTRACTION OF PLANT MATERIAL. Two methods of extraction were used. In the first method about 5 grams of chopped or ground dried plant material was extracted with 1 per cent hydrochloric acid at 80° C. for 4–6 hours. The resulting solution was filtered through fine paper and the filtrate was tested with the alkaloid reagents.

In the second method about 5 grams of chopped or ground dried plant material was extracted with Prollius fluid (*vide infra*) for 56 hours at room temperature with occasional stirring. The organic layer was separated and evaporated to dryness at room temperature. The residue was dissolved in 1 per cent hydrochloric acid by heating to 80° C. for 1 hour. The resulting solution was filtered through fine paper and the filtrate tested with the alkaloid reagents.

The second method was used to supplement the first when sufficient plant material was available. It proved useful in clarifying tests which had doubtful results on the basis of the first method alone.

REAGENTS. The following formulations of the alkaloid test reagents were based on Henry's directions (1929) with certain modifications.

Prollius Fluid. Ether, chloroform, alcohol, and ammonia were mixed in the ratio of 25:8:2.8:1 (by volume).

Mayer's Reagent. Dry mercuric chloride (6.8 g.) and potassium iodide (25 g.) were dissolved separately in water and diluted to make one liter of solution.

Hager's Reagent. A saturated aqueous solution of picric acid.

Wagner's Reagent. Iodine (13 g.) was dissolved in 1 N aqueous potassium iodide to make one liter of solution.

Dragendorff's Reagent. Neutral bismuth nitrate (20 g.) was dissolved in 30 g. cold conc. nitric acid (30 per cent). The solution was filtered and 68 g. potassium iodide in 60 ml. water was added. The resulting solution was allowed to stand for 24 hours, was filtered and diluted to 250 ml. with water.

Silicotungstic Acid Reagent. An aqueous solution of the acid, 0.1 N.

Sonnenschein's Reagent. A warm 4 N solution of disodium hydrogen phosphate was acidified with conc. nitric acid (pH 3). A slight excess of a saturated solution of ammonium

KEY TO ABBREVIATIONS IN TABLE I

The results of the spot tests are given in the following order and abbreviated form:

BINOMIAL	The accepted botanical name. The authority is omitted to conserve space. An asterisk (*) indicates introduced species.
LOCAL NAME	The Hawaiian or vernacular name, if known.
LOCALITY	The nearest town or other prominent map feature.
DATE COLLECTED	Date of actual collection in the field.
DATE TESTED	Date of actual application of spot tests.
PLANT PART(S)	B–bark, Br–branchlet, F–fruit, Fl–flower, H–herb or whole plant, L–leaf, R–root or underground part, S–seed, St–stem, W–wood, I–immature, M–mature.
ALKALOID REAGENTS	M–Mayer's, P–Picric Acid (Hager's), I–Iodine (Wagner's), D–Dragendorff's, S–Sonnenschein's, T–Silicotungstic Acid.
PRECIPITATES	With hydrochloric acid (HCl) or Prollius extracts (organic solvents and ammonia), classified on a tr (trace), + (light), ++ (heavy) basis. A — indicates no precipitation and a ? indicates that the test was meaningless.

TABLE I
RESULTS OF SPOT TESTS FOR ALKALOIDS
(Plants are listed alphabetically within each taxon.)

BINOMIAL	LOCAL NAME	LOCALITY	DATE COLLECTED	DATE TESTED	PLANT PART(S)	ALKALOID PRECIPITATES	
						HCl	Prollius
AMARANTHACEAE							
Charpentiera obovata	Papala	Kawaiiki trail, Oahu	23 Jul 57	14 Aug 57	Br, L, St	S+, D+, I+, M+, T+, P+	
C. ovata	Papala	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	L, St	S++, D++, I++, M++, T++, P++	S−, D−, I−, M−, T−, P−
ANACARDIACEAE							
*Schinus terebinthifolius**	Wilelaiki, Christmas Berry	Tantalus, Oahu	21 Dec 56	1 Oct 57	B, Br, F	Str, D−, I−, M−, T+, P−	
APOCYNACEAE							
Allamanda cathartica var. *Hendersonii**	Lani-ali'i, Allamanda	UH campus, Oahu	24 Feb 57	19 Mar 57	F, L, R, St	S−, D++, I++, M−, T−, P−	S++, D++, I++, M++, T++, P++
Alyxia olivaeformis	Maile	Koolau, Oahu	28 Oct 56	4 May 57	Br, F, L, St	S+, D++, I+, M++, T+, P++	S++, D++, I++, M++, T++, P++
Ochrosia sandwicensis	Holei	Laie trail, Oahu	— Oct 56	20 Mar 57	B, R	S++, D++, I++, M++, T++, P++	S++, D++, I++, M++, T++, P++
O. sandwicensis	Holei	Pupukea-Kahuku, Oahu	2 Oct 57	4 Oct 57	IF, MF	S++, D++, I++, M+, T++, P+	
Rauvolfia Degeneri	Hao	Mokuleia, Oahu	?	1 May 57	B	S++, D++, I++, M++, T++, P++	S++, D++, I++, M++, T++, P++
R. mauiensis	Hao	Hana district, Maui	?	1 May 57	B	S+, D+, I+, M+, T+, P−	S+, D+, I+, M+, T+, P+
R. sandwicensis	Hao	Aiea trail, Oahu	?	1 May 57	B	S++, D++, I++, M++, T++, P++	S++, D++, I++, M++, T++, P++
AQUIFOLIACEAE							
Ilex anomala	Kawa'u	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D+, I+, M+, Ttr, P−	Str, D+, I+ M?, T+, P−
ARALIACEAE							
Tetraplasandra sp.	Ohe	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D+, I+, M+, T++, P?	
BORAGINACEAE							
Heliotropium anomalum	Hinahina	Mokapu Point, Oahu	20 Jul 57	13 Aug 57	Br, L, Fl, R	Str, D−, Itr, M−, Ttr, Ptr	
CAPRIFOLIACEAE							
Lonicera japonica	Honekakala, Honeysuckle	Aiea trail, Koolau, Oahu	6 Jan 57	1 Oct 57	F, L, St	S+, D+, Itr, M−, T+, P−	

TABLE I—*Continued*

BINOMIAL	LOCAL NAME	LOCALITY	DATE COLLECTED	DATE TESTED	PLANT PART(S)	ALKALOID PRECIPITATES	
						HCl	Prollius
CHENOPODIACEAE							
Chenopodium oahuense	'Aweoweo, 'Aheahea	Pohakea Pass, Oahu	26 Nov 56	4 May 57	Fl, L, St	S++, D++, I+, M+, T++, P+	
COMPOSITAE							
Artemisia australis	'Ahinahina	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	Br, L	S+, D−, I−, M−, T+, P−	
Dubautia plantaginea	Na'ena'e	Pupukea, Oahu	28 Oct 56	4 May 57	F, L, St	S++, D++, I+, M+, T++, P+	
Lipochaeta integrifolia	Nehe	Mokapu Point, Oahu	20 Jul 57	11 Aug 57	Br, F, L	Str, Dtr, I−, M−, Ttr, P−	
CONVOLVULACEAE							
Ipomoea alba		Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	F, L, St	S++, D++, I++, M++, T++, P+	
I. pes-caprae	Pohuehue	Mokapu Point, Oahu	20 Jul 57	13 Aug 57	Fl, L, St	Str, Dtr, Itr, M−, T+, P−	
Jacquemontia sandwicensis	Pa'u-o-Hi'i-aka, Kakua-o-Hi'i-aka	Barbers Point, Oahu	16 Dec 56	4 May 57	Br, Fl, L, St	S+, D+, I+, M+, T+, P+	S++, D++, I++, M+, T++, P++
CYPERACEAE							
Cladium Meyenii	'Aha-niu	Aiea trail, Koolau, Oahu	6 Jan 57	30 Sep 57	F, Fl, L, R, St	S−, D−, I−, M−, T−, P−	
Gahnia gahniaeformis	Uki ?	Aiea trail, Oahu	6 Jan 57	4 May 57	L, R, St	S+, D−, I−, M−, T+, P−	S+, D−, I−, Mtr, Ttr, P−
DIOSCOREACEAE							
Dioscorea bulbifera	Hoi	Waiahole trail, Oahu	2 Mar 57	20 Mar 57	Aerial bulblet	S++, D++, I++, M+, T++, P+	S+, D+, I+, M−, Ttr, P−
D. bulbifera	Hoi	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	L, R, St	S++, D++, Itr, M−, T++, P−	S−, D−, I−, M−, T−, P−
D. pentaphylla	Pi'a	Kawaiiki ditch trail, Oahu	23 Jul 57	14 Aug 57	L, St	S+, D+, I+, M−, T+, P−	
EBENACEAE							
Diospyros ferrea var. *sandwicensis*	Lama	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	L, St	S−, D−, I−, M−, T−, P−	
D. ferrea var. *sandwicensis*	Lama	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D−, I−, M−, T++, P−	

D. Hillebrandii	Lama	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Br, IF, L, St	Str, D−, I−, M−, T+, P−	S−, D−, I−, M−, T+, P−
EPACRIDACEAE							
Styphelia Tameiameiae	Pukiawe	Kawaiiki ditch trail, Oahu	7 Oct 56	4 May 57	F, L, St	S−, D−, I−, M−, T−, P−	
EUPHORBIACEAE							
Aleurites moluccana	Kukui, Candlenut tree	UH campus, Oahu	24 Feb 57	19 Mar 57	F	S+, D+, I ?, M+, T++, Ptr	S−, D−, I−, M−, T−, P−
A. moluccana	Kukui, Candlenut tree	UH campus, Oahu	24 Feb 57	19 Mar 57	B, Br, L, St	S−, D−, I+, M−, T−, P−	S+, D+, I+, M−, T+, P ?
Antidesma platyphyllum	Ha'a, Hame	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	Str, Dtr, Itr, M−, T+, P−	S−, D−, I−, M−, T−, P−
A. pulvinatum	Mehame, Hame	Kawaiiki ditch trail, Oahu	23 Jul 57	14 Aug 57	L, St	S+, Dtr, I−, M−, T+, P−	
Euphorbia celastroides	'Akoko, Koko	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Br, Fl, L, St	S+, D+, Itr, Mtr, T+, P ?	Str, Dtr, I+, M+, Ttr, Ptr
E. clusiaefolia	'Akoko, Koko	Aiea trail, Oahu	6 Jan 57	1 May 57	F, L, St	S−, D−, I−, M−, T−, P−	
E. Degeneri var. *Degeneri*	'Akoko, Koko	Mokapu Point, Oahu	20 Jul 57	14 Aug 57	Fl, L, St	S−, D−, I−, M−, T−, P−	
E. Hillebrandii var. *waimanoana*	'Akoko, Koko	Kawaiiki ditch trail, Oahu	7 Oct 56	10 Oct 57	Br, F	Str, D−, I−, M−, T+, P−	
GLEICHENIACEAE							
Dicranopteris linearis	Uluhe, Unuhe	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	Fronds, R, Spores	S−, D−, I−, M−, T−, P−	
GOODENIACEAE							
Scaevola Gaudichaudiana	Naupaka-kuahiwi	Aiea trail, Oahu	6 Jan 57	1 May 57	Fl, L, St	S+, D+, I+, M+, T+, P+	S+, D++, I++, M++, T+, P+
LABIATAE							
Phyllostegia grandiflora var. *grandiflora*	Kapana	Pohakea Pass, Oahu	26 Nov 56	4 May 57	F, L, St	S+, D+, I+, M−, T+, P−	Str, D+, I+, Mtr, T−, P−
LAURACEAE							
Cassytha filiformis	Kauna'oapehu	Pohakea Pass, Waianae, Oahu	26 Nov 56	1 Oct 57	L, St	S−, D−, I−, M−, T−, P−	
LEGUMINOSAE							
Acacia Koa	Koa	Tantalus, Oahu	21 Dec 56	4 May 57	Br, F, L, St	S+, D+, I+, M+, T++, P+	S−, D+, I+, M−, T+, P−
A. Koa	Koa	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	B, R	S+, D+, I+, Mtr, T+, P−	
*Leucaena glauca**	Koa-haole	UH campus, Oahu	4 Mar 57	20 Mar 57	Br, F, Fl, L, St	S++, D+, I−, M+, T++, P−	S+, D−, I−, M−, T−, P−

TABLE I—*Continued*

BINOMIAL	LOCAL NAME	LOCALITY	DATE COLLECTED	DATE TESTED	PLANT PART(S)	ALKALOID PRECIPITATES	
						HCl	Prollius
LILIACEAE							
Dianella sandwicensis...	'Uki'uki	Kawaiiki ditch trail, Oahu	23 Jul 57	11 Aug 57	F, L, R, St	Str, D−, Itr, Mtr, Ttr, Ptr	
Smilax sandwicensis....	Hoi-kuahiwi	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	Str, Dtr, Itr, Mtr, Ttr, Ptr	Str, D+, Itr, Mtr, Ttr, Ptr
LOBELIACEAE							
Clermontia Kakeana....	'Oha-wai, 'Oha	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	F, L, St	S++, D++, I++, M+, T++, P++	S+, Dtr, Itr, M−, Ttr, Ptr
Cyanea angustifolia....	'Oha-wai, 'Oha	Pupukea, Oahu	28 Oct 56	3 May 57	Br, F, Fl, L, St	S++, D++, I++, M++, T++, P++	S++, D++, I+, M++, T++, P+
LOGANIACEAE							
Labordia tinifolia var. *tinifolia*.....		Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	MF, L, St	Str, Dtr, Itr, M ?, Ttr, P ?	
LYCOPODIACEAE							
Lycopodium cernuum...	Huluhulu-a-'iole	Aiea trail, Oahu	6 Jan 57	4 May 57	Br, L, St	Str, Dtr, Itr, M−, T+, P−	Str, Dtr, Itr, Mtr, T+, P−
L. phyllanthum.....	Wawae-'iole	Aiea trail, Oahu	6 Jan 57	1 Oct 57	L, Spores, St	S++, D++, I+, M+, T++, Ptr	
Psilotum nudum.....	Moa	Mokapu Point, Oahu	20 Jul 57	13 Aug 57	L, Spores, St	S+, D+, Itr, M−, T+, P−	
LYTHRACEAE							
*Cuphea carthagenensis**..	Tarweed	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Fl, L, St	S+, D+, I+, Mtr, T+, P ?	
MALVACEAE							
Hibiscus Arnottianus....	Koki'o-ke'oke'o	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	L, St	S+, D−, I−, M−, T+, P−	
Sida cordifolia..... (*Side fallax*)	'Ilima	Mokapu Point, Oahu	20 Jul 57	14 Aug 57	Fl, L, St	Str, D−, I−, M−, Ttr, P−	
MYOPORACEAE							
Myoporum sandwicense var. *stellatum*.....	Naio, Bastard Sandalwood	Barbers Point, Oahu	16 Dec 56	1 May 57	Br, F, Fl, L, St	S++, D++, I+, M+, T++, P++	S++, D++, I++, M++, T++, P++

MYRSINACEAE							
Myrsine Lessertiana	Kolea	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	L, St	S++, D++, I++, M++, T++, P++	
MYRTACEAE							
*Eugenia Cumini**	Java Plum	Waiahole trail, Oahu	2 Mar 57	22 Mar 57	B, L, St	S+, D−, I+, M−, T−, P−	S+, Dtr, I+, Mtr, T−, P−
E. sandwicensis	'Ohi'a-ha	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D−, I−, M−, Ttr, P−	
Metrosideros collina ssp. *polymorpha*, var. *glabrifolia*	'Ohi'a-lehua	Aiea trail, Oahu	6 Jan 57	4 May 57	Fl, L, St	Str, D+, Itr, M−, T+, Ptr	
M. macropus	'Ohi'a-lehua	Aiea trail, Oahu	6 Jan 57	4 May 57	Fl, L, St	S++, D+, I+, M−, T++, Ptr	
*Psidium Cattleianum**	Strawberry Guava, Waiawi-'ula'ula	Kawaiiki ditch trail, Oahu	23 Jul 57	11 Aug 57	Br, F, L, St	Str, D−, Itr, M−, Ttr, P−	
*P. Guajava**	Guava, Kuawa	Waiahole trail, Oahu	2 Mar 57	19 Mar 57	IF, L, St	S−, D−, I−, M−, T−, P−	S−, D−, I−, M−, T−, P−
NYCTAGINACEAE							
Boerhavia diffusa	Alena	Mokapu Point, Oahu	20 Jul 57	13 Aug 57	Fl, L, St	S−, Dtr, Itr, M−, Ttr, P−	
Ceodes umbellifera		Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Br, L, St	S++, D++, I++, M++, T++, P++	
OLEACEAE							
Osmanthus sandwicensis	Olopua	Aiea trail, Oahu	6 Jan 57	1 May 57	Br, F, L, St	S+, D+, I+, M+, T+, P+	S++, D++, I++, M+, T++, P+
ORCHIDACEAE							
*Spathoglottis plicata**	Philippine Ground Orchid	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Fl, L, R, S	S+, D+, I+, M−, T+, Ptr	
PALMACEAE							
Pritchardia sp.	Loulu	Summit, Castle trail, Oahu	— Jun 57	11 Aug 57	MS	S+, D+, I+, Mtr, T+, P ?	
PANDANACEAE							
Freycinetia arborea	'Ie'ie	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	L, St	S+, D+, I+, M−, T+, P−	
Pandanus odoratissimus	Hala	Waiahole trail, Oahu	2 Mar 57	22 Mar 57	MF, L, R, St, Prop Roots	S−, D−, I−, M−, T−, P−	S+, D ?, I−, M−, T−, P−
PASSIFLORACEAE							
*Passiflora edulis**	Liliko'i, Passion Fruit	UH campus, Oahu	2 Mar 57	1 May 57	Br, L, St	S++, D++, I+, M+, T++, P+	S++, D++, I++, M++, T++, P++
P. edulis cv. *flavicarpa**	Yellow-fruited Liliko'i	Cultivated plant	— Jul 57	11 Aug 57	MF	S++, D++, I++, M++, T++, P++	
*P. suberosa**	Huehue-haole	Tantalus, Oahu	21 Dec 56	1 Oct 57	F, L, St	S+, Dtr, I−, M−, T+, P−	

TABLE 1—*Continued*

BINOMIAL	LOCAL NAME	LOCALITY	DATE COLLECTED	DATE TESTED	PLANT PART(S)	ALKALOID PRECIPITATES	
						HCl	Prollius
PIPERACEAE							
*Piper methysticum**	'Awa	Waiahole trial, Oahu	2 Mar 57	22 Mar 57	L, R, St	S+, D+, I ?, M+, T+, Ptr	S++, D+, I+, M+, T+, P+
PITTOSPORACEAE							
Pittosporum glabrum var. *glabrum*	Ho'awa	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	IF, MF, L, St	S+, D+, Itr, M−, T+, P−	
P. sulcatum var. *sulcatum*	Ho'awa	Aiea trail, Oahu	6 Jan 57	10 Oct 57	F, L, St	Str, Dtr, Itr, M−, T+, P−	
PLUMBAGINACEAE							
Plumbago zeylanica	'Ilie'e	Pohakea Pass, Waianae, Oahu	26 Nov 56	30 Sep 57	F, Fl, L, St	S−, D−, I−, M−, T−, P−	
POLYPODIACEAE							
Microlepia setosa	Palapalai, Palai	Pohakea Pass, Oahu	26 Nov 56	4 May 57	R, St, Fronds	S++, D+, I−, M−, T+, P−	S−, D−, I++, M−, T−, P−
Sadleria cyatheoides	'Ama'u	Aiea trail, Oahu	6 Jan 57	4 May 57	R, St, Fronds	S−, D−, I−, M−, T−, P−	S−, D−, I−, M−, T−, P−
Sphenomeris chinensis	Pala'a	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	Fronds, R, Spores	Str, D−, I−, M−, Ttr, P−	
RUBIACEAE							
Bobea elatior	'Ahakea	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D+, Itr, M−, T++, P−	S+, D++, I+, M+, T+, Ptr
Canthium odoratum	Walahe'e, alahe'e	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D+, I−, M+, T+, P+	S+, D+, I+, M+, T+, P+
Coprosma foliosa	Pilo	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	L, St	S+, D+, I+, M−, T+, P ?	
Gouldia terminalis	Manono	Manoa Cliff trail, Oahu	6 Aug 57	21 Aug 57	MF, Fl, L, St	Str, Dtr, I−, M−, T+, P−	
*Morinda citrifolia**	Noni	Waiahole trail, Oahu	22 Feb 57	20 Mar 57	L, St	S+, D++, I+, M++, T++, P+	S+, D−, I−, M−, T+, P−
Psychotria hexandra var. *Rockii*			?	4 May 57	L, St	S+, Dtr, I−, M−, T+, P−	
Straussia kaduana	Kopiko-kea	Pupukea-Kahuku, Oahu	2 Oct 57	4 Oct 57	F, L, R, St	S++, D++, I++, M++, T++, P++	
S. Mariniana	Kopiko	Kawaiiki ditch trail, Oahu	23 Jul 57	14 Aug 57	Br, Fl, L, St	S−, D−, I−, M−, T−, P−	S−, D−, I−, M−, T−, P−

S. Mariniana	Kopiko	Kawaiiki ditch trail, Oahu	23 Jul 57	14 Aug 57	ML	S−, D−, I−, M−, Ttr, P−	
S. Mariniana	Kopiko	Kawaiiki ditch trail, Oahu	23 Jul 57	14 Aug 57	IF, MF	S+, D+, I+, M−, T+, Ptr	
RUTACEAE							
Pelea clusiaefolia	Alani	Aiea trail, Oahu	6 Jan 57	4 May 57	B, F, L, St	S+, D+, I+, M−, T++, P−	
P. Wawraeana	Alani	Aiea trail, Oahu	6 Jan 57	22 Mar 57	L, St	S+, D+, I++, Mtr, Ttr, P−	S+, D+, I+, M−, Ttr, P−
P. Wawraeana var. *tenuifolia*	Alani	Aiea trail, Oahu	6 Jan 57	22 Mar 57	L, St	S++, D++, I++, M+, T++, P−	S++, D++, I++, M+, T+, P+
SANTALACEAE							
Santalum Freycinetianum	'Ili-ahi	Aiea trail, Oahu	6 Jan 57	4 May 57	F, L, St	S+, D+, I−, M−, T+, P−	Str, Dtr, Itr, M−, T+, P−
SAPOTACEAE							
Planchonella (*Sideroxylon*) *sandwicensis*	'Ala'a	Manoa Cliff trail, Oahu	19 Oct 57	25 Oct 57	Fl, L, R, St	S++, D+, I+, M+, T++, P+	
TACCACEAE							
*Tacca Chantrieri**		Foster Gardens, Oahu (cultivated)	16 Dec 56	30 Sep 57	F, L, St	S+, D+, I+, Mtr, T++, P−	
*T. Leontopetaloides**	Pia	Puna, Hawaii	16 Dec 56	19 Mar 57	R	S++, D++, I++, M+, T+, P−	S++, D++, I++, M+, T+, P+
THYMELAEACEAE							
Wikstroemia oahuensis	'Akia	Aiea trail, Oahu	6 Jan 57	4 May 57	Fl, L, St	Str, D+, Itr, Mtr, T+, P−	S+, D+, I+, M ?, Ttr, Ptr
TILIACEAE							
Elaeocarpus bifidus	Kalia	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	L, St	S−, D−, I−, M−, Ttr, P−	
URTICACEAE							
Boehmeria grandis		Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	Fl, L, St	S+, D−, I−, M−, T+, P−	S+, D+, Itr, M+, T+, P−
Pipturus albidus	Mamaki	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	L, St	S−, D−, I−, M−, T−, P−	
Touchardia latifolia	Olona	Manoa Cliff trail, Oahu	6 Aug 57	19 Aug 57	Br, F, L, St	S++, D++, I+, M+, T++, P+	S−, D−, I−, M−, T−, P−
VERBENACEAE							
*Verbena litoralis**	Ha'uoi, owi	Kawaiiki ditch trail, Oahu	23 Jul 57	13 Aug 57	Fl, L, St	S+, D+, I+, Mtr, T+, Ptr	
ZYGOPHYLLACEAE							
Tribulus cistoides	Nohu	Mokapu Point, Oahu	20 Jul 57	11 Aug 57	Fl, L, St	S+, D+, I+, M−, T+, P−	

TABLE 2
SPECIES SHOWING POSITIVE TESTS WITH THE SIX REAGENTS

BINOMIAL	FAMILY	PLANT PART(S) TESTED
Acacia Koa	Leguminosae	Branchlet, Fruit
Allamanda cathartica var. *Hendersonii**	Apocynaceae	Fruit, Leaves, Root, Stem
Alyxia oliviaeformis	Apocynaceae	Branchlet, Fruit
Canthium odoratum	Rubiaceae	Fruit, Leaves, Stem
Ceodes umbellifera	Nyctaginaceae	Branchlet
Charpentiera obovata	Amaranthaceae	Branchlet
C. ovata	Amaranthaceae	Leaves, Stem
Chenopodium oahuense	Chenopodiaceae	Flowers, Leaves, Stem
Clermontia Kakeana	Lobeliaceae	Fruit, Leaves, Stem
Cyanea angustifolia	Lobeliaceae	Branchlet, Fruit, Flowers
Dioscorea bulbifera	Dioscoreaceae	Aerial bulblets
Dubautia plantaginea	Compositae	Fruit, Leaves, Stem
Ipomoea alba	Convolvulaceae	Fruit, Leaves, Stem
Jacquemontia sandwicensis	Convolvulaceae	Branchlet, Flowers
*Morinda citrifolia**	Rubiaceae	Leaves, Stem
Myoporum sandwicense var. *stellatum*	Myoporaceae	Branchlet, Fruit, Flowers
Myrsine Lessertiana	Myrsinaceae	Leaves, Stem
Ochrosia sandwicensis	Apocynaceae	Bark, Root, Fruit
Osmanthus sandwicensis	Oleaceae	Branchlet, Fruit
*Passiflora edulis**	Passifloraceae	Branchlet, Mature fruit
Pelea Waurateana var. *tenuifolia*	Rutaceae	Leaves, Stem
*Piper methysticum**	Piperaceae	Leaves, Root, Stem
Planchonella (Sideroxylon) sandwicensis	Sapotaceae	Flowers, Leaves, Stem, Root
Rauvolfia Degeneri	Apocynaceae	Bark
R. mauiensis	Apocynaceae	Bark
R. sandwicensis	Apocynaceae	Bark
Scaevola Gaudichaudiana	Goodeniaceae	Flowers, Leaves, Stem
Straussia kaduana	Rubiaceae	Fruit, Leaves, Root, Stem
*Tacca Leontopetaloides**	Taccaceae	Tuber
Touchardia latifolia	Urticaceae	Branchlet, Fruit

An asterisk (*) after the name denotes an introduced species.

molybdate was added. The resulting yellow precipitate was filtered, washed with water, acidified with conc. nitric acid, and dissolved in a hot 2 N solution of sodium carbonate. The solution was evaporated to dryness and ignited at dull red heat until all the ammonium salts had volatilized. The residue was moistened with conc. nitric acid and again ignited. The product, sodium phosphomolybdate, was dissolved in ten times its weight of a mixture of one volume of conc. nitric acid and nine volumes of water.

TESTING PROCEDURE. Approximately 0.2 ml. of the plant extract was treated with *ca.* 0.1 ml. of the reagent on a watch glass. The precipitates (if any) usually formed immediately and the results were evaluated after ten minutes' standing. The precipitates were graded visually and estimated as trace, light, or heavy.

RESULTS AND DISCUSSION

Table 1 lists the results of the alkaloid tests which were carried out on 96 plant species, representing 77 genera and 49 families.

None of the test reagents was specific for alkaloids when used alone. However, when a species gave positive reactions with all six reagents, the presence of alkaloids was strongly suggested. Conversely, those plants giving consistently negative tests almost certainly did not contain alkaloids.

Included in the above table are species of nine genera which have never been tested for

alkaloids before. They are: *Charpentiera*, *Clermontia*, *Cyanea*, *Dubautia*, *Jacquemontia*, *Pelea*, *Straussia*, *Tacca*, and *Touchardia*. Those endemic to the Hawaiian Islands are: *Clermontia*, *Cyanea*, *Dubautia*, *Straussia*, and *Touchardia*. Pioneering work in these genera should afford fruitful rewards for workers interested in alkaloids.

SUMMARY

Preliminary investigations concerning the presence of alkaloids in 96 species of Hawaiian plants, representing 77 genera and 49 families, indicated that 30 species contained alkaloids. Thirty-two species gave negative tests while the remainder were listed as doubtful.

The testing procedure consisted of extracting various plant parts with hydrochloric acid and testing the extract separately with six test reagents. The acid extraction was supplemented in some cases by an ammonia-mixed organic solvent solution. The precipitates were graded visually on a trace, light, or heavy basis. Only those species which gave a light and/or heavy precipitate with all six test reagents were classified as containing alkaloids.

Among the 30 species which gave positive tests for alkaloids, 9 genera were represented for which no previous alkaloid information exists. These 9 genera, 5 of which are endemic to the Hawaiian Islands, should afford fruitful sources for future studies for alkaloids.

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News Note

EXECUTIVE COMMITTEE, 10th PACIFIC SCIENCE CONGRESS

The National Academy of Sciences–National Research Council and the Bishop Museum, at whose invitation the 10th Pacific Science Congress of the Pacific Science Association will meet in Hawaii in August–September 1961, have appointed the following to be members of the Executive Committee of the Congress:

President of the Congress: Dr. Laurence H. Snyder, President of the University of Hawaii, Honolulu, Hawaii

Secretary-General: Harold J. Coolidge, Executive Director of the Pacific Science Board, N.A.S.–N.R.C., Washington, D.C.

Members

From the U. S. mainland

Knowles A. Ryerson, National Academy of Sciences representative on the Council of the Pacific Science Association and Dean of the College of Agriculture, University of California, Berkeley, California

Dr. G. P. Murdock, Professor of Anthropology, Yale University, New Haven, Connecticut

Dr. Harry Wexler, Director, Office of Scientific Services, U. S. Weather Bureau, Washington, D.C.

From Hawaii

Dr. Cyril E. Pemberton, Bishop Museum representative on the Council of the Pacific Science Association and Entomologist Emeritus of the Experiment Station of the Hawaiian Sugar Planters' Association, Honolulu, Hawaii

Dr. Robert W. Hiatt, Dean of the Graduate School and Director of Research, University of Hawaii, Honolulu, Hawaii

Dr. Alexander Spoehr, Director, Bernice P. Bishop Museum, Honolulu, Hawaii

The Executive Committee has overall responsibility for the organization and operation of the Congress. A preliminary schematic organization of the Congress program has been drawn up and President Snyder is appointing organizers for the program sections. The scientists selected to organize the program will be getting in touch with Standing Committees and with other scientists in the participating countries.

At the request of the Secretary-General all Congress enquiries should be addressed to him as follows:

Secretary-General
10th Pacific Science Congress
Bishop Museum, Honolulu 17, Hawaii

CHAIRMEN, STANDING COMMITTEES OF THE PACIFIC SCIENCE ASSOCIATION

The President of the Ninth Pacific Science Congress, Air Marshal Muni M. Vejyant-Rangsrisht, has now received confirmation of his appointments of Standing Committee Chairmen. The list of Chairmen is presented herewith:

Animal Improvement

Professor T. J. Robinson, Department of Animal Husbandry, The University of Sydney, Sydney, N.S.W., Australia

Anthropology and Social Sciences

Dr. Bernard P. Groslier, 4, rue Toricelli, Paris 17e, France

Botany

Dr. F. R. Fosberg, Pacific Vegetation Project, c/o National Research Council, 2101 Con-

stitution Avenue, Washington 25, D.C., U.S.A.

Chemistry in the Development of Natural Resources

Dean Tab Nilanidhi, Faculty of Science, Chulalongkorn University, Bangkok, Thailand

Conservation

Dr. Ian McTaggart Cowan, Department of Zoology, University of British Columbia, Vancouver 8, Canada

Crops and Crop Improvement

Dr. Iso Reksohadiprodjo, Djalan Widoro, 3, Jogjakarta, Indonesia

Entomology

Dr. J. J. H. Szent-Ivany, Department of Agriculture, Stock and Fisheries, Port Moresby, Papua and New Guinea

Forestry

L. W. Bryan, Board of Agriculture and Forestry, P.O. Box 1761, Hilo, Hawaii

Freshwater Sciences

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